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Assessing the Effectiveness of the European Union Emissions Trading Scheme through the Oil and Gas Sector

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Assessing the Effectiveness of the EU ETS through the Oil and Gas Sector

by

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Dedication

I dedicate this work to my mother and father, to whom I owe so much.

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There are a number of people whose help I must acknowledge in bringing this work to completion. Firstly, Ben Leibowicz and John Butler who were influential in shaping my early thought process in putting together the methodology utilized in this study. I also owe Carey King huge thanks in his undertaking of an advisory role for this thesis at short notice and for his guidance in the latter months of constructing a discussion. Finally, it would be impossible not to acknowledge the help and guidance of Richard Chuchla. As a reader of this thesis, and as the program director of Energy and Earth Resources, he has contributed considerably to the development of my thought process and the way in which I approach problems and professional life.

Abstract

Assessing the Effectiveness of the European Union Emissions Trading Scheme through the Oil and Gas Sector

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Following the initiation of the European Union Emissions Trading Scheme (EU ETS) in 2005 the scheme has received significant criticism pertaining to a lack of transparency in its operational mechanics and an inability to present conclusive evidence that it has encouraged a reduction in monitored emissions. This study utilizes an adaptation of the event study methodology proposed by Ball and Brown (1968) and Fama et al. (1969) in order to assess the impact of the EU ETS on emissions in the European oil and gas sector as a sample reflective of the scheme on the whole. In doing so, this study compares the annual emissions of carbon dioxide, nitrous oxide and methane for dual listed, single listing and cross listed oil and gas companies on the New York Stock Exchange and the London Stock Exchange and how these emissions change over the period 2000-2017; from prior to the EU ETS until the period of most recent data availability. Analysis conducted on the data gathered infers that, while the EU ETS may have exerted some influence on operators' behavior, the scheme has generally been ineffective in achieving its goal of lowering emissions and encouraging economic growth.

This study also explores the limitations of the EU ETS and potential drivers of emissions changes for operators within the scheme. Through such discussion the intention is to better understand the tradeoff between the advantages of cap-and-trade, a quantity mechanism, and emissions taxation, a pricing mechanism. These mechanisms comprise the majority of the presently adopted emissions policies globally, including the EU ETS, and China's and Canada's emissions trading schemes. Therefore, in better understanding the implications and effects of these mechanisms, the intention is to contribute to the future adoption and implementation of global emissions policies.

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SECTION 1.1: INTRODUCTION TO THE EU ETS

Section 1.1.1: Context for the Development of the EU ETS

The establishment of the EU ETS comes as a consequence of global climate activism relating to climate change and greenhouse gas emissions (Bomberg, 2012; Skjaerseth, 2014). Roser-Renouf et al.'s (2014) summary of the origins of climate change activism points to its beginnings in the mid to late 20^{th} century, gaining mainstream popularity by the turn of the century, particularly in Europe. As a response to the resulting social pressures and its previous failure to instigate a carbon tax (Convery 2009) the European Commission, the legislative and decision-making body of the EU, considered regulatory changes in order to combat concerns relating to the emissions of greenhouse gases.

However, the regulatory conditions which resulted in the initiation of the EU ETS as we recognize it today can be traced back to the early 1990's with the signing of the United Nations Framework Convention on Climate Change in 1992. In 1997, the signing of the Kyoto Protocol would also influence the construction of the EU ETS (Shishlov, Morel and Bellassen, 2016; Organisation for Economic Co-operation and Development (OECD), 2018; Climate Policy Info Hub, 2019). Through the establishment of the Kyoto Protocol, the majority of Europe had committed to a reduction in greenhouse gas emissions of 8% between 1990 and the 2008-2012 period (European Commission, 2019c). Initially, the European Commission proposed a carbon tax in 1992 (Convery, 2009) while also arguing for the inclusion of emissions trading within the Kyoto Protocol in 1997. Over the course of five years, 1992 to 1997, the European Commission had rapidly shifted its standpoint, from fervently against to strongly in favor of emissions trading (Skjaerseth and Wettestad, 2009). Skjaerseth and Wettestad (2009) argue that this shift occurred as a result of three key drivers, the decision to include emissions trading within the Kyoto Protocol's commitments (including provisions pertaining to international trading), the attractiveness of cap-and-trade as a flexible market-based instrument, and the entrepreneurial approach favored by the European Commission in order to stimulate economic growth in the EU. Through a combination of these factors, and the learnings from a failure to impose a carbon tax (Convery, 2009) the EU was convinced and the EU ETS initiated Phase I in 2005 (European Commission, 2019a).

It is tempting to think of the European Commission, and by extension the EU, as a unified body acting as one. However, this is not the case. In reality, efforts by specific member states of the EU exerted strong influence on the position of the Commission overall (Convery, 2009; Skjaerseth and Wettestad, 2009). The activist efforts of the United Kingdom and Denmark, in particular, significantly influenced the position of the Commission (Convery, 2009). Germany's strong position within the EU itself, and its long term fixation upon renewable energies, also exerted considerable influence on the EU's motivations to develop a cap-and-trade scheme (Apunn, 2019).

Section 1.1.2: The EU ETS Cap-and-Trade Mechanism

As outlined in Section 1.2.1, the EU ETS is a multi-phase long term instrument designed to reduce greenhouse gas emissions across a number of high-emitting sectors across Europe. The cap-and-trade mechanism through which the scheme operates is based upon the premise of establishing a market for carbon. The market should then dictate the value of one unit (a metric ton in this case) of carbon dioxide, or any equivalent monitored emission. In theory, the scheme should therefore encourage the emitters to reduce their emissions or risk impacting their bottom line, although the challenge lies in encouraging innovation and efficiency without bankrupting emitters (Skjaerseth and Wettestad, 2009). Under the conditions that emitters cannot meet the caps established by the scheme, the carbon market allows emitters to purchase unused allowances from other parties within the market. Additionally, this market has evolved over the course of the scheme, from national carbon markets in Phase II to a singular market across the entire EU ETS in Phase III (Schaefer, 2018). The total emissions allowance for each industry is adjusted annually, becoming more stringent each year and therefore increasing the requirement for operators to either purchase allowances or reduce their emissions (OECD, 2018; Environmental Defense Fund, 2019). Through this method, the EU ETS' intention is to ensure the lowering of emissions by operators by imposing financial penalties if they fail to do so or fail to acquire additional allowances (Skjaerseth and Wettestad, 2009). In this way, a successful EU ETS cap-and-trade with a reasonable cost of emissions and severe financial penalties for lack of compliance should encourage a reduction in emissions within the monitored industries year-on-year.

As a market-based response to greenhouse gas emissions, cap-and-trade is intended to represent a method of reducing emissions that allows the market to set the price for carbon in a similar way in which the price of companies on the public markets are dictated by market supply and demand (Environmental Defense Fund, 2019). By giving pricing power to the market, and controlling annual caps, the EU's intention was to allow for efficient emissions pricing while allowing for certainty regarding future emissions caps (Center for Climate and Energy Solutions, 2019). As noted by Koch et al. (2016) the scheme was relatively successful in establishing a functioning carbon market whereby the cost of carbon, and other monitored emissions, responded organically to regulatory events, in the same way as the stock markets react. This flexibility is also noted by Goulder and Schein (2013) as a potential advantage of cap-and-trade over emissions taxation. The U.S. Environmental Protection Agency (2019) states that effectively designed cap-and-trade programs provide control over the variable in question, flexibility for the emitters to tailor their compliance path to their needs, and incentives for efficiency, innovation and early pollution reductions. In principle, this is how the EU ETS was intended to operate. As the EU reduced the allowances for emitters year-on-year (the "caps"), the intention was that companies would be incentivized to pursue efficiency and innovation to reduce their emissions. As an alternative, the EU ETS would allow emitters to purchase unused allowances from other emitters in the market (the "trade"). In this way, the EU ETS was intended to represent a multinational collaboration across multiple industries with a set commitment to lowering emissions through time. Allowances were anticipated to be in sufficient demand to keep the price of emissions sufficiently buoyant so as to incentivize the pursuit of efficiency and innovation in reducing emissions. However, in utilizing a market based approach through cap-and-trade the EU exposed itself to significant emissions pricing risk and exposed the scheme to potential exploitation by the markets.

Section 1.1.3: Scheme Outline to Date

Phase I (2005-2007)

The initial phase of the EU ETS represented a three year pilot to prepare participants for full adoption of the scheme during Phase II. The second phase was intended to align with the meeting of the EU's commitments to the Kyoto Protocol (Climate Policy Info Hub, 2019; European Commission, 2019a). This first phase exclusively covered carbon dioxide emissions from power generation and energy-intensive industries, including the oil and gas upstream industry and oil refineries, with free allowances and a 40 euro penalty per metric ton released above compliance with these allowances (European Commission, 2019a). In doing so, the EU established the world's first carbon market and established the necessary infrastructure for continued monitoring and verification of emissions within the sectors covered by the scheme (Organisation for Economic Co-operation and Development, 2018; Climate Policy Info Hub, 2019; European Commission, 2019a). This phase also established the first effective price of carbon. Over this pilot phase, the price of carbon experienced significant fluctuations, starting at roughly 10 euros per metric ton of carbon dioxide (EpMTC) and closing the phase at around the same price

(Organisation for Economic Co-operation and Development, 2018). However, throughout much of 2006 the price held between 20 and 30 euros per metric ton (see Figure 1.1).

Figure 1.1: Cost of carbon throughout the EU ETS from 2005 to 2015. Sourced from the OECD (2018). Note the consistent decrease in the cost of carbon over the entirety of the graph and steep reductions associated with particular events for example the 2009-2010 Hungarian CER scandal.

However, due to the fact that caps were set based upon projected future emissions allowances during this phase exceeded the total emissions, essentially negating the effective price of carbon established upon initiation of this phase (OECD, 2018). Consequently, the EU ETS came under early scrutiny and was subject to significant early criticism, a trend which would continue throughout the later phases.

Phase II (2008-2012)

The second phase of the EU ETS was intended to coincide with the initiation of the first period of the Kyoto Protocol (Convery 2009; Skjaerseth and Wettestad, 2009; Climate Policy Info Hub, 2019; European Commission, 2019a). The scope of the EU ETS was expanded to include carbon dioxide emissions from concrete production and the nitrous oxide emissions originating from the production of nitric acid (Climate Policy Info Hub, 2019; European Commission, 2019a). Additionally, during the final months of this phase carbon dioxide emissions produced by the aviation industry within participating countries, which now included Norway, Iceland and Liechtenstein, were incorporated (European Commission, 2019a). Given the monitoring and verification practices established during Phase I, caps were set for Phase II based upon this historical data from the prior phase. Carbon dioxide emissions caps decreased by 6.5% which resulted in the first cap auctions, with a non-compliance penalty of 100 euros per metric ton (European Commission, 2019a). In total, 28 billion metric tons worth of allowances were traded over the course of Phase II aligning with the highest price achieved by caps throughout the EU ETS of roughly 35 euros (see Figure 1.1) (Organisation for Economic Co-operation and Development, 2018; European Commission, 2019a). The majority of these caps were traded via brokerage networks and exchanges, not through auction and caps were set on a national basis for each ETS member country not based upon a cap for the EU ETS as a whole (European Commission, 2019a). Again, the EU ETS was subject to criticism for this reliance on brokerage networks, and the associated cost of commissions.

Phase III (2013-2020)

The third phase of the EU ETS expanded the scope of the scheme to consider the emission of perfluorocarbons in addition to the consideration of the mining and smelting industries (European Commission, 2019b). Additionally, Phase III established a scheme-wide cap, as opposed to the previous method of setting individual caps for each member country (Convery, 2009; Organisation for Economic Co-operation and Development, 2018). Phase III also established auction as the default process by which caps were traded, rather than via brokerage networks and exchanges (European Commission, 2019b). This decision came in response to the significant criticisms following the over-reliance upon brokerages during Phase II (Convery, 2009). Through mandating the use of the auctioning process, the EU ETS also reduced the allocation of free caps which was restricted specifically to the development and deployment of renewable energy and carbon capture and storage technologies (European Commission, 2019b), though there has been allocation of free allowances outside these industries since (Convery 2009; Grosjean et al., 2014). The development of such technologies was covered under free caps allocated as part of the New Entrants Reserve (European Commission, 2017; 2018). As Phase III ends in 2020, Phase IV will result in proposed further reductions in the number of allowances distributed. The early regulatory proposals concerning Phase IV have coincided with a slight rebound in cap price noted by (Koch et al., 2016) with the effective cost of carbon expected to rise from around 14 euros in April 2018 to 30 euros in 2021 (European Commission, 2019b).

Section 1.1.4: Criticisms of the EU ETS

The EU ETS has been widely criticized both for issues pertaining to the emissions market itself and the regulatory framework supporting the allocation of allowances and construction and regulation of the emissions market. Given that the scheme was the world's first established carbon market (European Commission, 2019a), and the controversial nature of its policy, it is not surprising that critiques are frequent. It is also clear that a number of key failings identified a significant structural weakness in the way that the EU ETS was established. Webster's (2017) and Reyes and Gilbertson's (2010) interpretations of the failings of the scheme are based upon criticism of its capitalistic approach and therefore its over emphasis upon economic and not environmental considerations. However, by focusing on a social critique of the EU ETS, there is a tendency to detract from its technical failings.

De Perthuis (2011) categorizes three fundamental technical failings of the scheme: a propensity to allow value-added tax (VAT) carousel fraud, Certified Emissions Reductions (CER) trading and allowance thefts. The first of the three is not a specific issue with emissions markets or cap-and-trade but pertains to the cross-border trading of allowances whereby the seller charges buyers VAT but does not repay the correct tax authorities. The second, CER trading, refers to the 2010 Hungarian CER scandal whereby the EU ETS failed to reliably account for previously verified emissions. As a result, previously utilized emissions allowances were sold as unused allowances. The latter of the three critiques noted by de Perthuis (2011) refers to the prevalence of allowance thefts within the EU ETS, which accounted for roughly 0.15% of the emissions traded in January 2011. All three of de Perthuis' (2011) critiques address explicit failings in the structure of the EU ETS and though VAT carousel fraud is not specific to cap-and-trade the EU's lax approach to establishing the logistics of the EU ETS led to an opportunity to exploit the scheme. Furthermore, the occurrence of allowance theft and a lack of transparency concerning CERs significantly damaged the reputation of the EU ETS with the 2010 scandal aligning with a decline in carbon prices (see Figure 1.1).

The EU ETS' lack of transparency in the trading and auctioning of allowances has received heavy criticism more broadly. This lack of transparency makes the scheme susceptible to the critiques noted by de Perthuis (2011), Webster (2017) and Reyes and Gilbertson (2010) and manifests in the carbon market in a lack of faith in the market mechanism itself. This lack of faith relates to a significant flaw in the scheme: the low price of emission on the EU ETS and, by extension, the higher costs imposed by other emissions taxes and floor prices within individual EU ETS member states. These taxes and floor prices are highlighted in the analysis by Skeates and Innes (2018), who attribute an equivalent cost of roughly $16 per metric ton of carbon dioxide during Phase III of the EU ETS (see Figure 1.2).

CARBON PRICING INITIATIVE	CARBON PRICE (USD PER TON OF CO_2e)	CARBON PRICING INITIATIVE	CARBON PRICE (USD PER TON OF CO_2e)
Sweden Carbon Tax	139	New Zealand ETS, California CaT, Ontario CaT, Québec CaT	15
Switzerland Carbon Tax, Liechtenstein Carbon Tax	101	Beijing Pilot ETS	9
Finland Carbon Tax	77	Portugal Carbon Tax, Switzerland ETS	8
Norway Carbon Tax (Upper)	64	Shenzhen Pilot ETS	7
France Carbon Tax	55	Shanghai Pilot ETS, Saitama ETS, Tokyo CaT, Colombia Carbon Tax, Latvia Carbon Tax	6
Iceland Carbon Tax	36	Chile Carbon Tax	5
Denmark Carbon Tax (Fossil Fuels)	29	RGGI, Chongqing Pilot ETS, Norway Carbon Tax (Lower)	4
British Columbia Carbon Tax	27	Fujian Pilot ETS, Mexico Carbon Tax (Upper), Japan Carbon Tax	3
UK Carbon Price Floor, Spain Carbon Tax, Ireland Carbon Tax, Denmark Carbon Tax (F-Gases)	25	Estonia Carbon Tax, Hubei Pilot ETS, Guangdong Pilot ETS	2
Alberta CCIR, Alberta Carbon Tax	23	Tianjin Pilot ETS	1
Slovenia Carbon Tax, Korea ETS	21	Mexico Carbon Tax (Lower), Poland Carbon Tax, Ukraine Carbon Tax	<1
EU ETS	16		

Figure 1.2: Equivalent cost of carbon under various carbon policies globally. Sourced from Skeates and Innes (2018). Note the relatively low equivalent price of the EU ETS and the higher floor prices for countries under the jurisdiction of the EU ETS.

The relatively low cost of emissions for the EU ETS relative to the unilateral floor prices for a number of its member states raise significant questions as to the effectiveness of the scheme. Appunn and Sherman (2018) highlight this issue in their discussion of the effectiveness of the EU ETS and it is intuitive that a low carbon price in the EU ETS relative to member state floor prices makes it both difficult to establish its effectiveness as an initiative and a logistical challenge to operate efficiently. The introduction of a floor price in the United Kingdom and carbon taxation in the Scandinavian states suggests the significant lack of member state faith which continues to hinder the EU ETS. Koch et al. (2016) argue that the low carbon price of the EU ETS is reflective of event-induced price drops concentrated within the earlier years of the scheme's initiation, which aligns with de Perthuis' (2011) interpretation of the 2010 Hungarian CER scandal. Through Koch et al.'s (2016) event study, they infer that carbon price drops correlate strongly with press releases pertaining to CER and allowance scandals and makes for a cogent argument that the criticisms of the EU ETS have resulted in a depressed carbon price; which has gone on to further damage the reputation and efficacy of the scheme. Under a low cost of carbon, the incentive to pursue innovation and efficiency is less for emitters and therefore the efficacy of the cap-and-trade mechanism for the EU ETS (as described in Section 1.2.3) is significantly weakened. Grosjean et al. (2014) also point to the structural failings of the EU ETS as an explanation for the crash in carbon prices, citing exogenous shocks, insufficient scheme credibility and market flaws as drivers of the crash, aligning with de Perthuis' (2011) and Koch et al.'s (2016) interpretations. However it is worth acknowledging that Koch et al. (2016) also identify positive pricing response to releases pertaining to Phase IV regulations and therefore there is potential value in the later phases of the scheme.

Criticisms of the EU ETS' structure and transparency are ubiquitous throughout the literature. Hintermann's (2015) study on market manipulation suggests that market power, particularly in the early stages of the scheme, is the dominant factor in determining compliance with the scheme. The findings of the Hintermann (2015) study essentially align with the observations by de Perthuis (2011) and Grosjean et al. (2014) that the EU ETS emissions market is inherently flawed and easily manipulated. Hintermann (2015) argues that there are circumstances whereby the inflation of permit prices through purchasing excess permits would benefit dominant market players in the long run, shown in a sample set of 10 power companies. This critique builds on the works of Hintermann (2010) and Hahn and Stavins (2011) and collectively these studies directly question an implicit assumption made within this thesis: that the introduction of increasingly stringent emissions permits introduces an increasingly relevant incentive for operators to reduce emissions over the course of the EU ETS. Although this assumption pervades the analysis, it is key to consider that given the structural failings of the EU ETS it is plausible that there was a failure to establish such an incentive. While the works of Hintermann (2010; 2015) mainly focus on Phase I of the EU ETS, this issue remains a pertinent consideration with regards to the conclusions generated under the scope of this thesis. Furthermore, criticism of the EU ETS for its lack of transparency and issues surrounding the occurrence of unilateral pricing mechanisms within EU ETS member states provide further considerations and limitations regarding the conclusions generated by this thesis.

Section 1.1.5: Potential Alternatives to the EU ETS

Given the numerous criticisms leveled at the EU ETS (see Section 1.2.4), and cap-and-trade generally, a number of alternative measures have been proposed, some of which are briefly displayed in Figure 1.2. As a quantity mechanism, a natural alternative to cap-and-trade is the option to utilize a pricing mechanism: carbon taxation (Weitzman 1974; Chiu et al., 2015; Zakeri et al., 2015; Wang et al., 2016; Tang, Wang and Wei, 2019) (see Section 5.3). There has been considerable debate as to whether carbon taxation would have been, and would be in the future, a better alternative to cap-and-trade, with a general consensus in the U.S. that the former would be a preferential option.

As shown by Skeates and Innes (2018) there has already been considerable adoption of carbon taxation both unilaterally within the EU ETS and outside the EU, for example in Canada. Within the economic community there is widespread support for carbon taxation as a more efficient and economically sound mechanism than cap-and-trade where there is a lack of transparency in the data (Cropper and Oates; Menanteau, Finon and Lamy, 2003) (see Section 5.3). Dissou and Siddiqui (2013) argued that progressive results can be achieved with carbon taxation either through low or high case tax levels. Progressive, in this case, is defined as beneficial in combatting income inequality and incentivizing greenhouse gas emissions reductions. However, more broadly, carbon taxation has been suggested it is a more efficient alternative to cap-and-trade due to its more transparent nature and the perception that is a more efficiency mechanism (Summers, 2007). Those in favor of these benefits frequently point to the issues discussed in Section 1.2.4 as an argument in supporting the implementation of carbon taxation over cap-and-trade; and it is broadly true that the use of carbon taxation would reduce the risks noted by de Perthuis (2011) and Hintermann (2010; 2015). Instead of addressing emissions quantities through the establishment of caps, carbon taxation (and emissions taxation generally) establishes a set price for carbon reflective of the verified emissions of the company or industry in question. There is no requirement to establish or regulate an emissions market, which reduces risks associated with the market (Zhu et al., 2018) though each mechanism has risks and uncertainties associated (Weitzman, 1974; Leibowicz, 2018) (see Section 1.2.4). By removing the market's ability to determine the cost of one unit of monitored emissions, emissions taxation also significantly reduces the opportunity for market manipulation (Hintermann, 2010; 2015). However, in implementing carbon taxation this opens further issues relating to potential tax fraud, in addition to a deviation away from the setting of explicit emissions allowances as in cap-and-trade. Therefore, although emissions taxation may be capable of solving issues raised by cap-and-trade including market crashes, allowance fraud and market manipulation (Hintermann, 2010; de Perthuis, 2011; Grosjean et al., 2014) emissions taxation is also subject to its own limitations and risk factors (Weitzman, 1974; Leibowicz, 2018).

From the literature it is clear that economists generally prefer taxation as an alternative to cap-and-trade (Summers, 2007). This appears to result from a tendency to prefer any option which reduces the requirement for heavy regulation. For those not from an economic school of thought, it is evident that cap-and-trade was considered a better alternative as, on a theoretical level, it allows greater control by the governing body (in this case the EU) over emissions reductions (Cropper and Oates, 1992; Menanteau, Finon and Lamy, 2003), which is the primary concern of environmentalists (Bomberg, 2012; Roser-Renouf, 2014; Skjaerseth, 2014). The reasoning behind this intuition lies in the fact that cap-and-trade allows the explicit identification of variable (in this case emissions) targets which can be tracked. Goulder and Schein (2013) addressed the advantages of carbon taxation versus cap-and-trade, highlighting the issues covered previously in this Section. Most specifically, Goulder and Schein (2013) point to a tradeoff between the Weitzman issue and Murray-Newell-Pizer issue; pricing uncertainty versus flexibility to respond to new information. The conclusions from Goulder and Schein (2013) suggest that carbon taxation, as previously noted, is more effective at mitigating pricing uncertainty while cap-and-trade is more effective at responding new information. This benefit of cap-and-trade is supported by the results from Koch et al.'s (2016) event study. The advantage of being able to respond to new information quickly makes the EU ETS more suitable for the event study analysis conducted as part of this thesis but overall may not make cap-and-trade a more viable option than emissions taxation, a fact noted by Goulder and Schein (2013).

Another alternative to the EU ETS is the approach adopted by the U.S.: to not implement a national carbon policy through either pricing or quantity mechanisms. There is no nationwide equivalent to cap-and-trade or emissions taxation in the U.S., although there is a Regional Greenhouse Gas Initiative on the east coast statewide policies in California and Oregon (Skeates and Innes, 2018; RGGI, 2019). There is some argument to be made that the emissions reduction from the U.S. is the result of efficient markets reflecting investor sentiment. Therefore as investor priorities shift towards low emissions alternatives, companies shift their practices to reflect investor sentiment in order to maintain and improve their market capitalization (Tomain, 1990).

However, there is strong evidence to suggest that it is in fact a combination of the broad change from coal to natural gas in the power market and the introduction of state-level policy for renewables that has resulted in such a reduction (US EPA, 2018). Thus far, the approach has proved empirically sound with the U.S. decreasing its carbon dioxide emissions annually at a greater rate than the United Kingdom (World Bank, 2019), which has a national floor price above the price set by the EU ETS (Skeates and Innes, 2018). Though the U.S. has withdrawn from its pledge to the Paris Agreement, it is clear that there is credibility behind the efficient market argument. However for now, the U.S. approach is producing results which suggests that there are alternatives to method adopted by the EU ETS (World Bank, 2019) and therefore it is important to acknowledge this alternative to the scheme.

SECTION 1.2: THE EFFECTIVENESS OF THE EU ETS

Section 1.2.1: Assessing the Effectiveness of the EU ETS

As a consequence of the EU ETS, the EU established an effective cost of carbon, and subsequently costs of nitrous oxide and perfluorocarbons, which could significantly impact the profitability of emitting companies operating within sectors governed by the scheme relative to their peers with less exposure to the scheme. As noted by Skjaerseth and Wettestad (2009) (see Section 1.2.2), a successful EU ETS would establish a cost of emissions, to encourage emitter innovation and efficiency, but would not establish such a cost at the expense of reducing economic growth in the region. Therefore, in assessing the impact of a cost of emissions two variables must be considered: emissions quantities and economic growth.

Verified emissions is evidently a key variable in the consideration of the effectiveness of the EU ETS. A successful emissions trading scheme should reduce emissions quantities as caps and allowances are reduced (Burtraw and Themann, 2018).

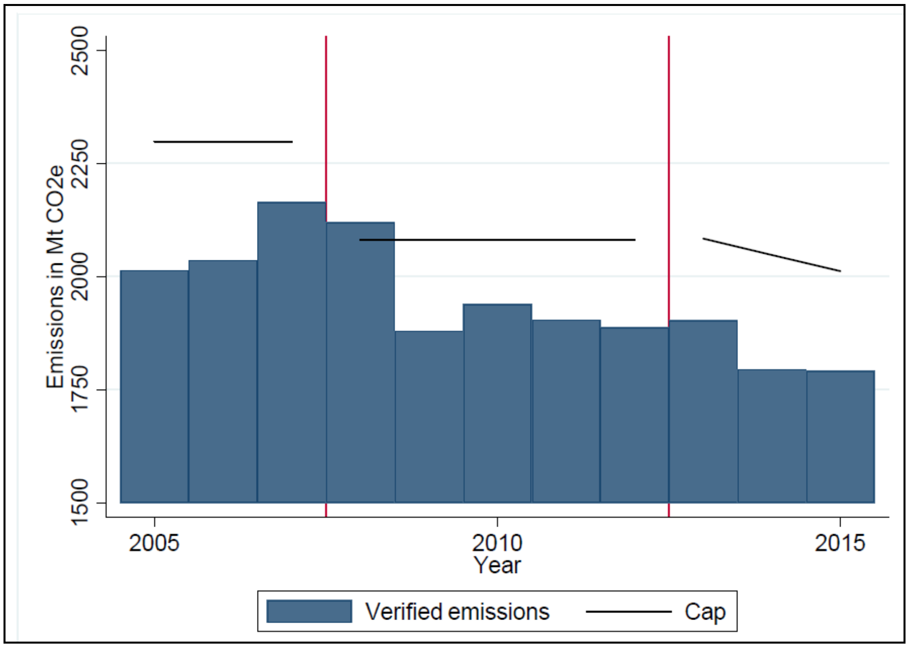

Figure 1.3: Changes in EU ETS total verified emissions from 2005 through 2015. Sourced from the OECD (2018). Note a decline in allowances ("caps") from Phase III (2013) onward.

According to the Organisation for Economic Co-operation and Development (2018), verified emissions from EU ETS installations decreased by approximately 15% between 2005 and the end of 2015 (see Figure 1.3).

However, the consideration of verified emissions as an isolated variable is not an effective method of assessing the efficacy of the EU ETS. Alternative measures that do not utilize cap-and trade-have also resulted in greater emissions reductions (see Section 1.2.5).

The occurrence of the economic recession in 2008 exerted considerable influence on the economic performance of emitters. In the oil and gas sector this manifested as a decrease in production and refining (Stevenson, 2018) and therefore a decrease in emissions. If the intention of the EU ETS is to both reduce emissions and encourage economic growth (Skjaerseth and Wettestad, 2009) then the Gross Domestic Product (GDP), and the rate by which emissions decrease relative to GDP emissions intensity must also be considered (see Figure 1.4). The EIA has examined U.S. electric power carbon dioxide emissions from 2000-2017. Fifty percent of the carbon dioxide emissions during this period of time as due to lower demand growth alone (EIA, 2017) (see Figure 1.5). Power accounts for over 50% of EU ETS emissions, therefore lower demand growth for power across the EU ETS would exert considerable impact on annual emissions and the perceived effectiveness of the scheme on the whole.

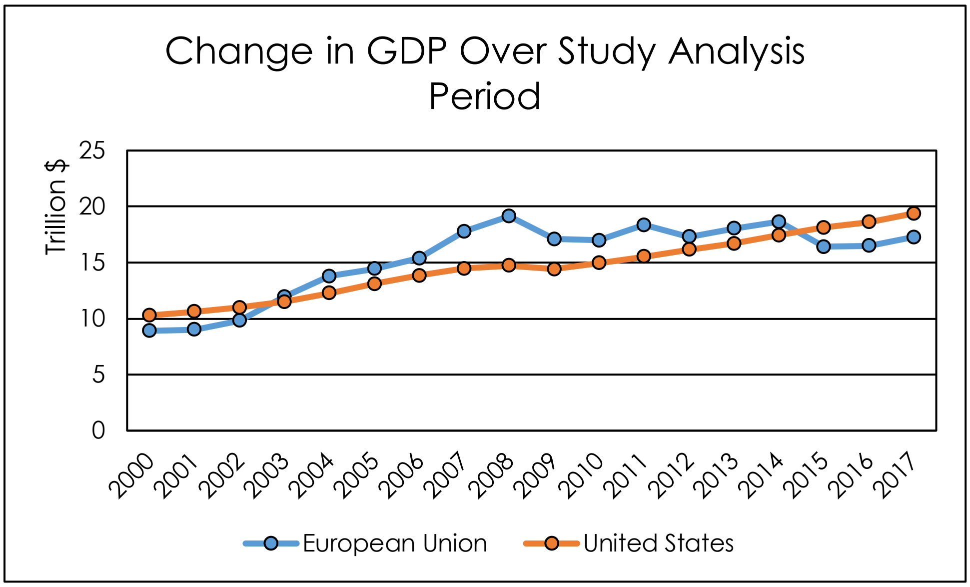

Figure 1.4: Change in GDP for the U.S. and the EU over the analysis period. Adapted from data sourced from the World Bank (2019). Note the consistent growth in U.S. GDP compared with a stalling and subsequent reduction of EU GDP between 2008 and 2017.

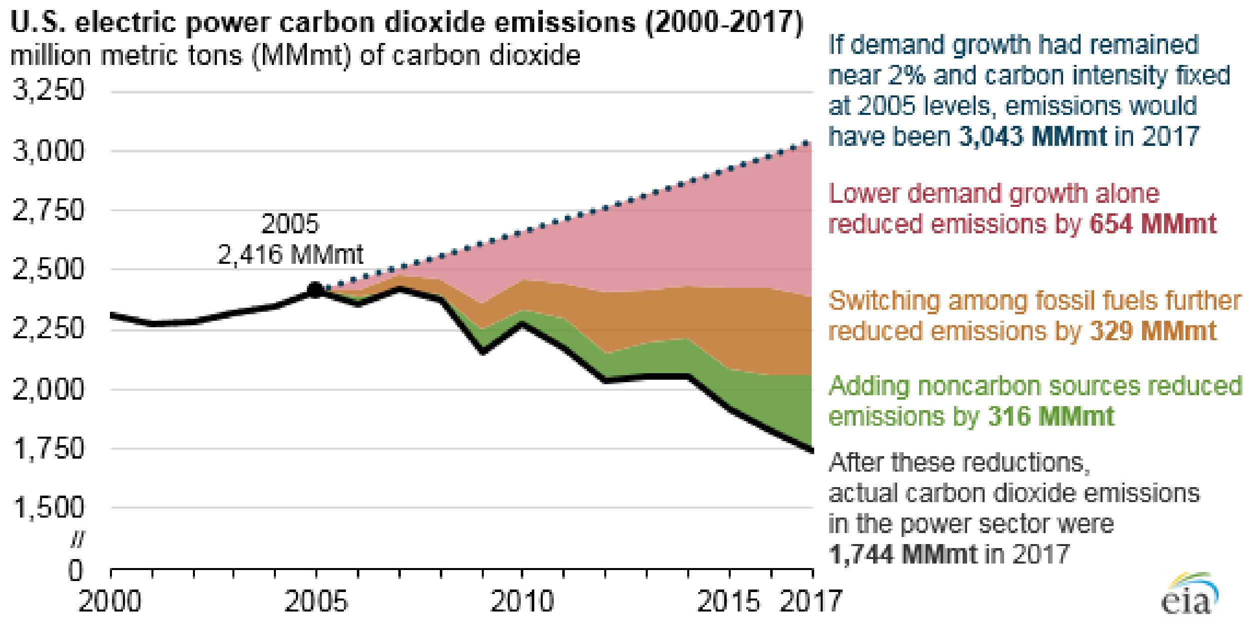

Figure 1.5: U.S. electric power carbon dioxide emissions (2000-2017). Sourced from the Energy Information Administration (EIA) (2017). Note that lower demand growth alone accounts for over 50% of the reduced emissions.

From Figure 1.4, it is apparent that EU GDP growth outpaced the U.S. throughout Phase I (2005-2007) and initially in Phase II (2008-2012) of the EU ETS. EU GDP growth stagnated after 2008 and began to decline, falling beneath U.S. GDP in 2015 during Phase III of the EU ETS. According to Figure 1.3, EU ETS verified emissions increased, and then subsequently declined, and stagnated across the 2005-2012 period. EU GDP growth also followed a similar trend. Within this same time frame, the global financial crisis was also taking shape, coming to a head in 2008. The alignment between EU GDP and emissions reductions, marked by an inflection point at the 2008 financial crisis, raises serious questions as to the effectiveness of the EU ETS in achieving a true reduction in emissions. The similarity of the trends noted in Figures 1.3 and 1.4 suggest that much of the emissions reductions achieved during the EU ETS is at least to some degree the result of a decline in economic growth resulting from the onset of the 2008 financial crisis. This conclusion is supported by the generous allowances relative to verified emissions (see Figure 1.3). The flat allocation of caps during Phase I and Phase II is consistently above the level of verified emissions, suggesting that the caps themselves were not sufficiently strict so as to incentivize innovation and efficiency in emissions reductions for operators within the scheme. Only in 2008 do operators' verified emissions exceed the allocated cap however given the onset of the financial crisis at this time it is impossible to differentiate reasons for the emissions reduction which followed between the result of a downturn in operations or a reduction resulting from innovation and efficiencies. The decreasing cap allowances apparent in Phase III and the coincident decrease in verified emissions (see Figure 1.3) lend some credence to the argument that the EU ETS exerted influence on a reduction during Phase III. However, given the downturn in EU GDP over the same period (see Figure 1.4) it is again impossible to categorically conclude that the EU ETS has been an effective mechanism in reducing verified emissions.

Section 1.3.2: The Effectiveness of the EU ETS: A German Case Study

In Section 1.2.5, potential alternatives to the EU ETS were discussed, including the approach of the U.S. Much attention has been drawn to the U.S. approach in comparison with Germany, which has maintained an anti-nuclear stance since long before the Fukushima-Daiichi disaster of 2011 (Breidthardt, 2011) and has displayed an energy policy which some have described as "reckless" (Der Spiegel, 2013). Given its influence within the EU and its pro-renewable approach, Germany has often been considered representative of the success of the EU (Magen, 2018) (and the EU ETS) on the whole. However, this pro-renewable approach has not necessarily produced the results which Germany, or the EU ETS had hoped for. Germany's commitment to reducing nuclear and its moratorium on hydraulic fracturing within its borders has led to a reliance on coal to back up intermittent renewables (see Figure 1.6). This was perversely promoted by clean dark spreads (for coal) which were higher than the clean spark spread (for gas), conditions which incentivize the use of coal over natural gas (a significantly lesser emitter of greenhouse gases) (Gonzalez 2018; Wilson and Staffell, 2018).

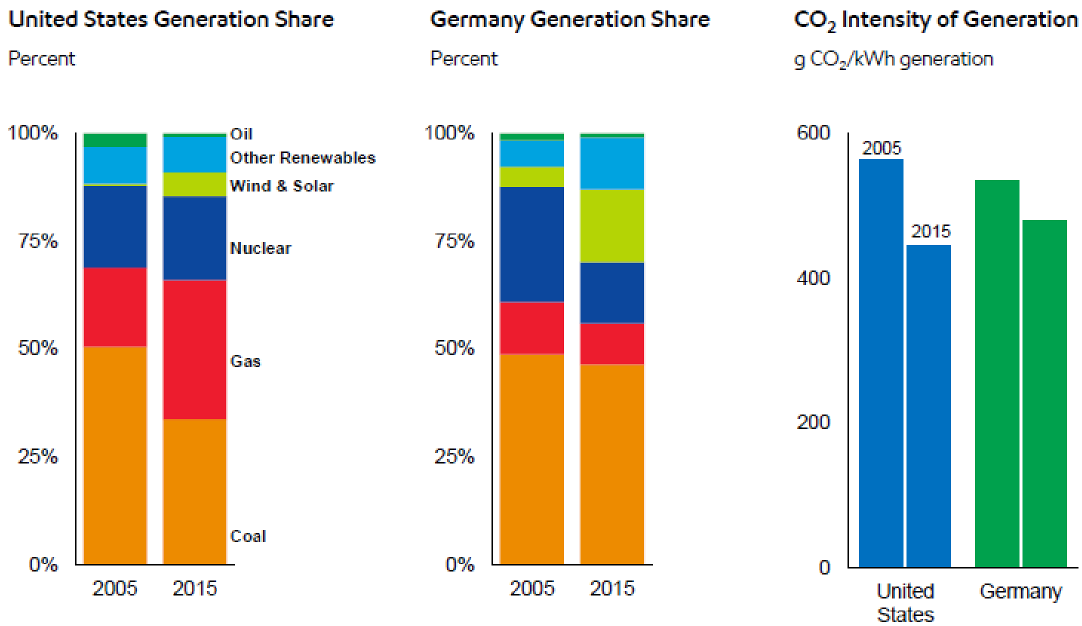

Figure 1.6: Power generation by source and collective CO_2 intensity for this generation for the U.S. and Germany. Sourced from ExxonMobil (2017). Note the difference in the percentage of power generation from coal in both countries.

Although Germany has committed to phasing out coal by 2038 (Wald, 2019) it is clear that in recent history the country has developed an energy policy which, while supporting the development of renewable energy, has facilitated the use of coal to meet a significant portion of the country's energy demand (Lehmann et al., 2015; Geddes, Schmidt and Steffen, 2018; Bianco, Driha and Sevilla-Jiménez, 2019). From the furthest right graph in Figure 1.6, it is apparent that, without cap-and-trade, the U.S. has been more successful than Germany in reducing the carbon dioxide intensity (carbon dioxide per unit of power produced) of electricity generation. This comes in some part from an increase in the amount of electricity generated by renewables over the 2005 through 2015 period. However, the majority of this improvement in the U.S. comes as result of coal to gas switching and an increase in the amount of electricity produced from natural gas (EIA;

2017, Green, 2018). Germany too has increased its generation from renewable sources, however it has failed to reduce the proportion of coal in its energy mix by a factor comparable with the U.S. As a consequence of these decisions, Germany has failed to significantly reduce the proportion of its electricity generated by coal and is exposed to geopolitical risk through a reliance upon Russian natural gas. An additional factor related to the introduction of the EU ETS is that any country operating under the scheme has been subject to a diminished clean spark spread. The clean spark spread describes the revenue generated for natural gas plant operators while accounting for the impact of emissions costs operating under a cap-and-trade scheme (CDC Climat Research, 2013) (see Equation 1).

Equation 1:

$$CSS = E - G - N_{CC} * P_{CC}$$

$CSS = Clean\ Spark\ Spread$

$E = Price\ of\ Electricity\ Sold$

$G = Cost\ of\ Gas\ Purchased$

$N_{CC} = Number\ of\ Carbon\ Credits\ Purchased$

$P_{CC} = Price\ of\ One\ Carbon\ Credit$

The clean dark spread refers to the same equation (Equation 1) but for coal as opposed to gas. As coal is a more carbon intensive power source than gas, it is subject to a higher cost of emissions. Thanks to the low cost of carbon credits on the EU ETS and a high cost of gas relative to coal, the clean spark spread diminished to a greater extent than the clean dark spread, with clean dark spreads often considerably above clean spark spreads in Europe (Carpenter and Abnett, 2018; KPMG, 2018) (see Figure 1.7). In other words, the low cost of carbon credits fell short of offsetting the price differential between gas and coal. Consequently, profit margins for natural gas plant operators are decreased relative to coal therefore making coal, a higher emitting power source, a more appealing and profitable power source for operators. This issue is compounded in Germany, where a shift away from nuclear power and a moratorium on hydraulic fracturing of shale left coal as one of the only resources remaining to generate base load cheaply and reliably. This example illustrates some of the limitations of the EU ETS.

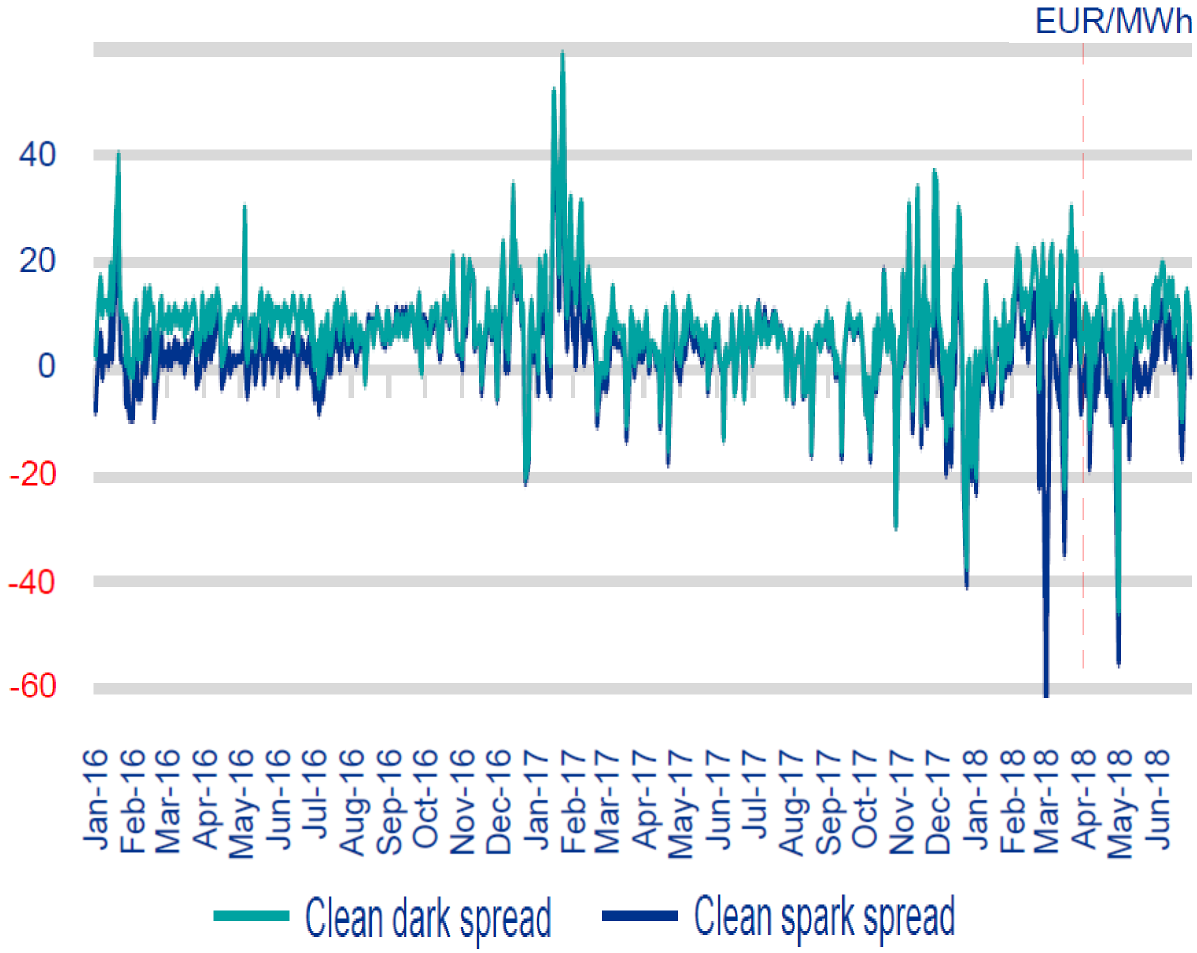

Figure 1.7: Evolution of the clean spark versus the clean dark spread over the latter portion of Phase III of the EU ETS. Adapted from KPMG (2018). Note the consistency with which the clean dark spread exceeds the clean spark spread, against the intentions of the EU ETS. EUR/MWh is Euros per megawatt hour.

Chapter 2: Outline of the Study

Section 2.1: Statement of Purpose

With the closure of Phase III of the EU ETS approaching in 2020, there has been considerable discussion regarding the effectiveness of the initiative in lowering the gaseous emissions from companies operating within the participating countries (see Section 1). In theory, the EU ETS was intended to encourage companies to decrease their carbon footprint and adopt alternative and renewable energy sources. The scheme focused primarily on the release of carbon dioxide during its initial Phase, with the introduction of nitrous oxide and perfluorocarbons during the later phases. However, participation in the scheme is only mandatory for companies operating in specific sectors for each of the aforementioned gases. The initiative has received significant criticism as a consequence of its lack of transparency and a lack of tangible evidence to suggest that it has successfully resulted in a decrease in recorded emissions within the sectors under its jurisdiction.

These sectors include power and heat generation, oil refineries, oil and gas upstream activities and a number of other energy intensive industries. Consequently, oil and gas companies have had significant exposure to the effects of the scheme, both in their direct operations and in the sale of their products, and therefore represent a reasonable basis to examine both the direct and indirect effects of the EU ETS and its associated amendments and additions. As the uptake of cap-and-trade and carbon pricing policies increases globally, and as the U.S. considers its own carbon policies, now is an appropriate time to assess these effects and whether the use of such initiatives is truly an effective method of reducing greenhouse gas emissions.

SECTION 2.2: HYPOTHESIS

The hypothesis of this study is that oil and gas companies operating within the purview of the EU ETS (represented by European operators) will display a more negative correlation between their long term economic performance and changes in the emissions of monitored gases (carbon dioxide and nitrous oxide) than companies operating outside the scope of the scheme (represented by U.S. operators). Within this overarching hypothesis there are two sub-hypotheses:

1. The overall correlations between economic performance and the emissions of monitored gases over the course of the EU ETS (2005-2017) will be more negative for European operators than for U.S. operators. For emissions not monitored by the EU ETS (in this case, methane) this trend should not be present or significantly less apparent.
2. The incremental correlations between economic performance and the emissions of monitored gases will become increasingly negative through each phase of the EU ETS for European operators while there should be little change for U.S. operators. For emissions not monitored by the EU ETS (in this case methane) this trend should not be present or significantly less apparent.

In contrast, the correlation between European operators' economic performance and emissions not monitored by the scheme (methane was selected as a basis for unmonitored emissions) should fail to display the trends hypothesized above and should show greater parity between European and U.S. operators than is the case for carbon dioxide and nitrous oxide. In the case that the above sub-hypotheses are accepted, the EU ETS could be regarded a relatively effective method of encouraging, either directly or indirectly, a reduction in greenhouse gas emissions.

The basis for this hypothesis lies in the understanding that the EU ETS intended to establish a link between economic performance and emissions to encourage emissions reductions while simultaneously stimulating business growth. Through utilizing a cap-and-trade mechanism, the

EU opted for a quantity method which allowed control over the emissions variables and allowed the market to set the equivalent cost of emissions. Over the course of the EU ETS, the EU has continued to reduce emissions allowances across the scheme which provides a stronger signal to operators that they should reduce emissions. An increase in emissions should result in greater external costs to operators either through a requirement to purchase additional allowances or through penalty payments to the EU ETS.

SECTION 2.3: LIMITATIONS OF ANALYSIS

It is very clear that many factors can influence the financial performance of companies and their emissions. Therefore, results conforming to the above hypothesis can only be used to suggest possible causality between the EU ETS and financial performance. Results conforming to the above hypothesis neither require the conclusions stated nor do they eliminate other causes of this correlation. As has already been shown (see Figure 1.5), in the case of the U.S. over 50% of the reduction of carbon dioxide emissions was due to reduced demand. This study does not attempt to disaggregate the reduction in power demand from the impact of the EU ETS. This factor is one of the many not analyzed in this study.

SECTION 2.4: DATASET CONSTRUCTION

Section 2.4.1: Selecting the Oil and Gas Sector as Representative of the EU ETS

By selecting the oil and gas industry, this thesis opens itself to the critique that its results are not reflective of the EU ETS on the whole. However, this decision was made upon the basis that; 1) conducting analysis across all sectors of the EU ETS would be too time consuming under the scope of this study, 2) many of the failings and results of the oil and gas sector under the EU ETS are shared by other sectors within the scheme 3) this author's personal interest in the sector itself. However, it is acknowledged that the analysis conducted within this thesis can only be used to for some very high level observations pertaining to the effect of the EU ETS on the oil and gas sector and cannot categorize the scheme as a whole.

Kortelainen (2018) noted an average decrease of 17.5% in total emissions for the 2005 through 2017 period across all sectors of the EU ETS. However, this decrease was strongly influenced by considerable decreases in the power and heat and lime and cement production sectors. Emissions in the oil and gas sector were not successfully reduced during this period, despite a significant decrease in the total emissions allocated to the sector by the EU ETS (see Figure 3.1). However, the results produced by the Kortelainen (2018) study also suggest that a failure to meet emissions allowances is a common trend across the EU ETS (see Figure 3.2). From Figure 3.2, it is apparent that oil and gas sector annual verified emission as a percentage of annual allowances generally follows the trends of the EU ETS collectively.

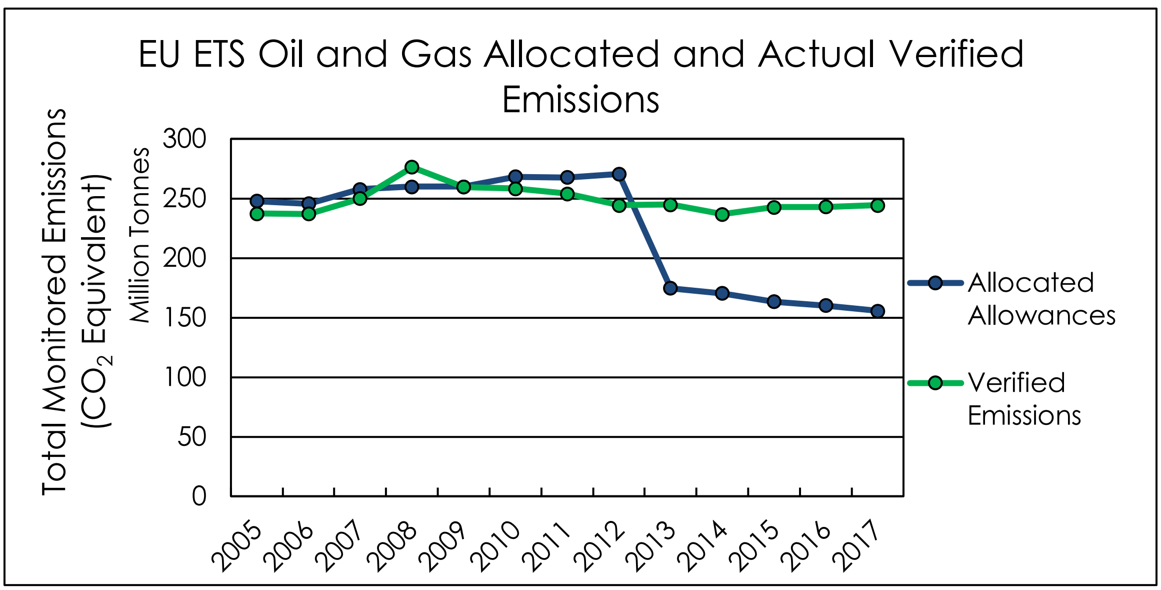

Figure 2.1: Verified versus allowed emissions for the oil and gas sector under the jurisdiction of the EU ETS. Data adapted from Kortelainen (2018). Note the flat lining of emissions from the oil and gas sector and the significant decrease in allocated allowances during Phase III of the EU ETS (2013 to 2020).

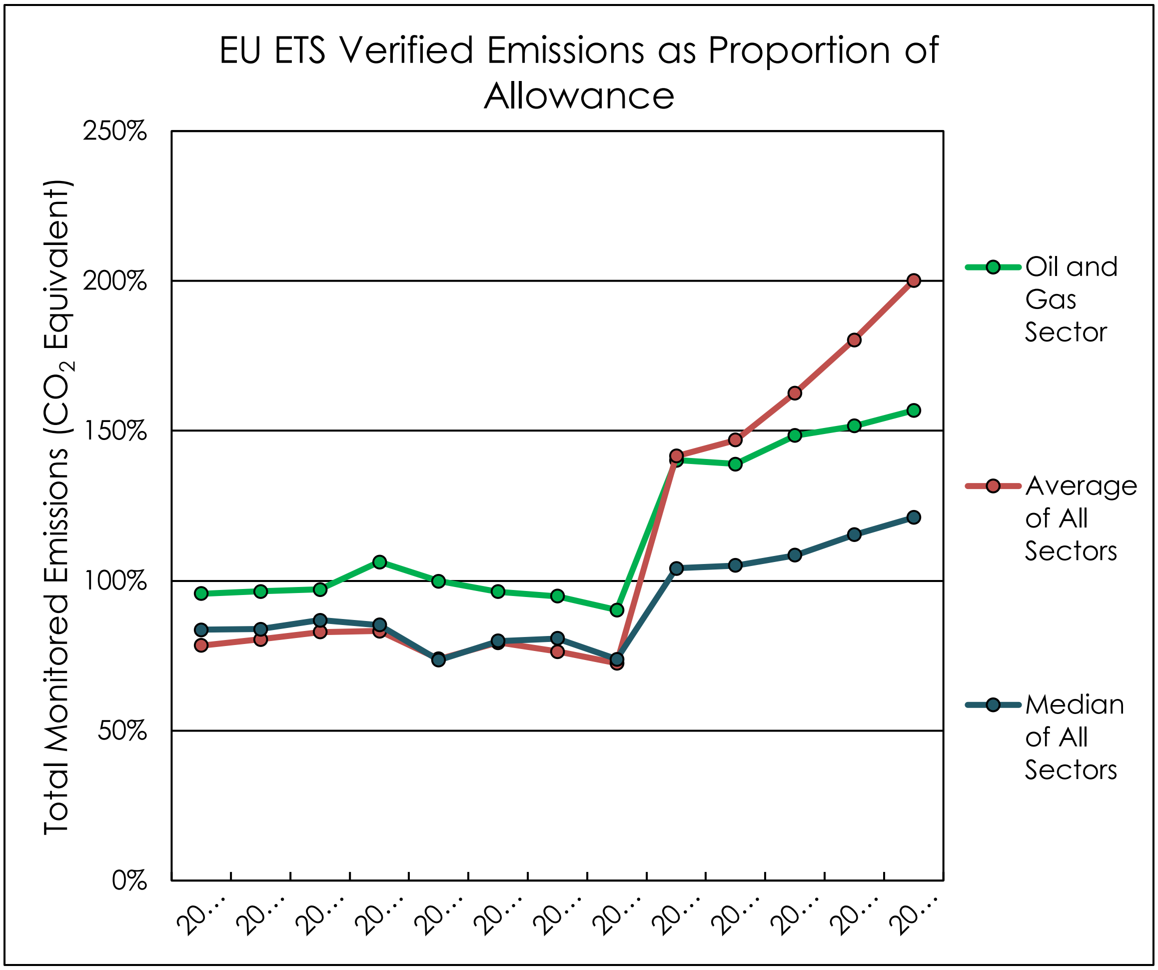

Figure 2.2: Verified versus allowed emissions for the oil and gas sector relative to other sectors under the jurisdiction of the EU ETS. Data adapted from Kortelainen (2018). Note the consistent exceedance of allowances across the entirety of the EU ETS following allowance reductions starting in 2013.

Chapter 3: Methodology

Section 3.1: Introduction to the Data

Section 3.1.1: Public Companies on the NYSE and LSE

In order to generate an indication of the effectiveness of the EU ETS on the oil and gas sector it was necessary to compare the performance of companies subject to the jurisdiction of the scheme against those which were not. This method essentially follows that of an event study though given the longevity of the EU ETS this specific application is unconventional. Typically, the approach outlined by Ball and Brown (1968) and Fama et al. (1969) is utilized over a period before and after a regulatory, company or macroeconomic event covering a period of months. However, given that the EU ETS is ongoing and has been active over multiple years the method employed in this study differs from those used in previous event studies. By utilizing this method, reliable sources of data for both companies operating within Europe and those operating within a comparable region not under the purview of the scheme. Consequently, the U.S. was selected as this comparable region due to a combination of the scale of its oil and gas sector and the availability of data. Associated with this availability of data, the presence of the New York Stock Exchange (NYSE) and the London Stock Exchange (LSE) in the U.S. and Europe respectively were identified as the most effective sources of information from which to construct the framework for the datasets for companies outside and under the jurisdiction of the EU ETS respectively. Given that both are public markets, companies listed on each exchange are required to publish annual and quarterly updates on company performance from which indicators of economic success could be gathered.

Additionally, the NYSE is the largest stock exchange in the world by market cap and therefore was identified as having more stringent listing requirements in addition to containing the stock offerings from a number of large companies which typically publish data more consistently and reliably than their smaller counterparts. The LSE was selected as an effective representation of companies operating within the jurisdiction of the EU ETS. This exchange was chosen as an alternative to the Euronext. Although the Euronext represents a wider sample across the EU, the number of oil and gas exploration companies is considerably smaller than is listed on the LSE: roughly 3 compared to 150 for the Euronext and LSE respectively. Furthermore, accessing verified and updated listings of companies on the Euronext proved significantly more challenging than for the LSE. Therefore, the updated and verified lists of oil and gas exploration companies were downloaded from the LSE and NYSE in order to build out the dataset framework for conducting this study.

Section 3.1.2: Building Out the Dataset Framework

Upon downloading the company listings from both exchanges it became clear that there were a number of companies listed on both the NYSE and the LSE. These three companies (Shell, Total and BP) are referred to as dual listed companies (DLCs). This means that they are incorporated in two different countries, agreeing to operate as if they were a single enterprise; however they remain separate legal entities (Bedi, Richards and Tennant, 2003). Given this dual listing on both the LSE and NYSE, such companies are inferred to have significant financial exposure to policies within both regions in which the company is listed (Europe and the U.S.). Consequently, DLCs are a key source of identifying the impact of the EU ETS on the regional economic performance of these companies. However, it is entirely unsuitable to analyze DLCs within datasets containing companies which do not have the same classification. Therefore, the DLCs (Shell, Total and BP) were separated from other companies analyzed, under the DLC dataset, within which there is a dataset for both Europe and the U.S. reflecting DLC emissions and economic performance for both regions.

In addition to the 3 DLCs analyzed, 20 companies were selected from each exchange. These companies represented, after the omission of the 3 DLCs, the 20 largest companies by market capitalization for each exchange. This selection criteria was finalized based upon the assumption that larger companies publish information more consistently and have typically been public for longer, meaning greater data availability, than their public counterparts. This dataset, comprising 20 NYSE-listed and 20 LSE-listed companies, contains cross-listed and single listing companies (CLaSLCs). A cross-listed company refers to an entity which is officially listed on one stock exchange, but stocks of which can be purchased on other international exchanges. An example of such would be ConocoPhillips which is officially listed on the NYSE but shares of which can be purchased through the LSE. Cross-listed companies were treated as single listing companies with regards to this analysis. Single listing companies are those which have one official listing on any exchange; an example would be EOG resources, which is listed only on the NYSE. Within the data gathered for this study single listing companies typically have the majority, or all of, their operations within their country of listing and therefore were inferred to have limited financial exposure to regulations outside their region of listing. Although this is often not the case for cross listed companies, it was logistically easier to group cross listed companies with single listing companies as they could not be directly compared with DLCs. The analysis framework for each of these datasets was therefore as follows:

- European data for DLCs was compared against the U.S. data for DLCs
- Total company data for LSE CLaSLCs was compared against total company data for NYSE CLaSLCs
- European data for LSE CLaSLCs was compared against U.S. data for NYSE CLaSLCs

In general the approach is to treat the U.S. companies as a control group to determine the effect of the EU ETS on the oil and gas sector. However, there are many parameters outside those studies which could have effected ether population.

In selecting a sample from each exchange it is important to acknowledge the limitations and reasoning behind the selection process. As stated previously, in selecting the 20 largest producers and refiners by market capitalization for each exchange it was intended to maximize data consistency and reliability. Through the selection of these 20 CLaSLCs, from the 125 and 152 oil and gas producers and refiners listed on the NYSE and LSE respectively, it was also intended that the sample datasets would reflect the performance of their respective exchanges on the whole (see Figure 3.1).

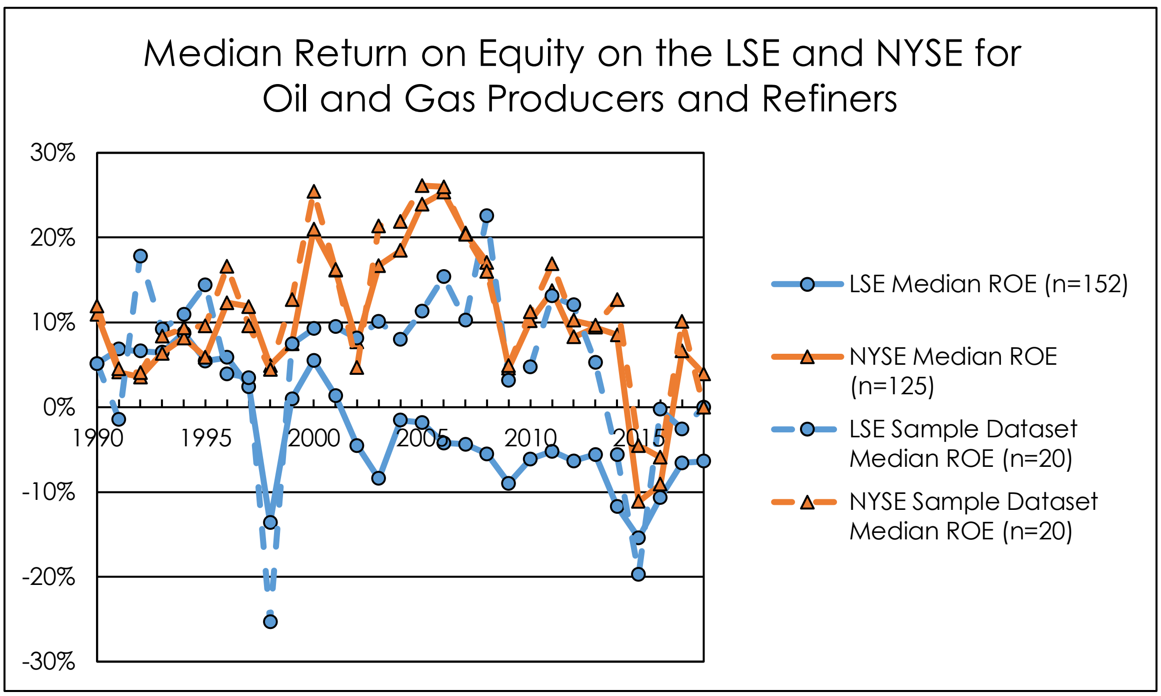

Figure 3.1: Median return on equity on the NYSE and LSE for oil and gas producers and refiners. EU ETS Phases I (2005-2007), II (2008-2012), III (2013-Present). Data sourced from Macrotrends (2018). Note the trend displayed by the LSE sample dataset (largest LSE operators) which performs considerably worse than all other groups.

Though it is evident that the NYSE sample is generally reflective of the trends displayed by the NYSE on the whole, there is a clear disparity between LSE sample and the LSE on the whole, particularly following 1997. This disparity is interpreted to occur as a consequence of the selection of the sample through market capitalization. The average current (as of December 2018) market capitalization of the CLaSLC LSE and NYSE datasets was roughly $880 million and $35 billion respectively, while the average IPO date was 2004 and 1990 respectively. From the disparity in the trends shown in Figure 1 and this information regarding the datasets it is clear that the NYSE and LSE are significantly different markets (this is also introduces potential limitations to the study method (see Section 5.4)). The NYSE on the whole is a much larger and more developed capital market, having a total market capitalization of approximately $3 trillion in the oil and gas sector compared to roughly $800 billion on the LSE. NYSE listed companies tend to be more mature and financially stable in comparison to the trend displayed by the younger operators listed on the LSE. Consequently, in selecting the largest 20 LSE listed operators by market capitalization this technique has sampled companies which are more mature and financially stable than the average company on the LSE. In contrast, NYSE listed companies are generally more mature and more financially stable than those listed on the LSE and therefore the sample of the 20 largest NYSE operators by market capitalization is more reflective of the NYSE market on the whole. That the LSE sample may not necessarily be representative of the general trend on the LSE is just one of the parameters not fully accounted for in this study.

SECTION 3.2: POPULATING THE DATASET FRAMEWORK

Section 3.2.1: Return on Equity and Return on Assets

All publicly traded companies are bound by strict regulations regarding their reporting of economic performance metrics which are broadly available to the public. Return on Equity (ROA) and Return on Assets (ROA) are calculable from annual and quarterly reports made available by each company, with the former representing Net Income (from the income statement) divided by Equity (from the balance sheet) and the latter representing Net Income divided by Assets (from the balance sheet) for the same reporting period. Both ROE and ROA are widely used throughout the financial services industry as key performance indicators for any company and therefore the ROE and ROA for companies listed on the NYSE and LSE are already calculated for any given financial period. Therefore, in the gathering of ROE and ROA data, from 1990 to 2017 for this study, all oil and gas producers and refiners on the NYSE and LSE (125 and 152 respectively) had this information pulled from the website “Macrotrends” and were accurate as of December 2018. However ROE and ROA are relatively easy to calculate, and the same information could be gathered from any number of websites which track the markets. The benefit of using Macrotrends is that its information storage period tends to be longer than its competitors so it is possible to track changes in ROE and ROA for up to twenty to thirty years for mature companies. Though the full analysis was only conducted on the 3 DLCs and 40 CLaSLCs (20 from both the LSE and NYSE) the ROE and ROA data were gathered in order to ensure that these datasets were either representative of the market as a whole or to shed light on the reasons behind any discrepancies in the sample dataset and the market from which the dataset was pulled (see Section 3.1.2). However, ROA was not included as part of the final methodology.

Section 3.2.2: Net Income and Regional Net Income

Net Income and Regional Net Income values were sourced from annual company reports and 10-K reports filed with the SEC for the period 2000 through 2017 for every year for which the information was published (which means at least every year that the company has been public). Net income for any public company is published at the bottom of the income statement and is the result of amending the total revenue (otherwise known as sales) earned by the company to reflect its operating expenses, interest expense, taxation, depreciation and amortization. By taking the total revenue and subtracting these five factors, the result is the Net Income of the company. Through using Net Income (which also factors into ROE and ROA; see Section 3.2.1) as an indicator of economic success, the intention was to ensure that all company activities were encompassed within these indicators (as opposed to metrics such as revenue and earnings before interest, taxation, depreciation and amortization (EBITDA) which do not). In doing so, any expenses which occurred directly as a result of innovations and efficiencies to reduce emissions or any expenses attributed to the purchase of emissions allowances were inferred to be reflected within Net Income.

In all cases, companies report the net income or loss for a given year on their annual income statement. Additionally, in most cases large companies also report their Net Income by geographic segment (i.e. the Regional Net Income that is attributable to the company's operations specifically in Europe or the U.S.). This Regional Net Income encompasses income and expenses specifically attributed to the geographic segment and therefore made for an excellent economic indicator of economic success for the purposes of this study. However, in the case of small companies it is significantly less common to find Net Income published by geographic segment. Where all of a small company's operations were focused within one region (in either Europe or the U.S.) then the value for Net Income was carried over as the company's Regional Net Income. Where Net Income was not published by geographic segment, and the company operated across multiple regions, Regional Net Income was calculated as a proportion of the value for Total Net Income for the company based upon the reported revenues by geographic segment. Revenue by geographic segment was always available, even in the absence of Net Income by geographic segment.

The use of regional revenue as an approximation for Regional Net Income is inherently limited in its approach and introduces considerable limitations into the method for this study. This approximation was used for one of the NYSE CLaSLCs, approximately three of the LSE CLaSLCs and none of the DLCs taken forward into the data analysis. By using this approximation, there are regional differences in expenses, such as those introduced by the EU ETS that may be disproportionately over or under represented in resulting approximation for Regional Net Income. It is therefore plausible that in using this approximation the results of this study have been skewed.

Section 3.2.3: Emissions and Regional Emissions

Sources of Emissions in the Oil and Gas Sector

Within the oil and gas industry there are a number of operations from which greenhouse gas emissions can be produced. Integrated oil and gas companies have both significant upstream (exploration and production) and downstream (refining and chemicals) components which are responsible for the emission of greenhouse gases. Therefore, in extrapolating regional emissions it is key to consider the geographic distribution of these operations so as best to account for the regional distribution of emissions for the integrated company. Shell (2018) note that:

> *"In 2017, around 50% of our direct GHG emissions came from our refineries and chemical plants. The production of oil, gas and GTL products accounted for around 45% of our GHG emissions, and our shipping activities accounted for around 2%."*

In comparison, ExxonMobil identify an approximate split of 55% of emissions from downstream and refining operations and 45% of emissions from upstream activities (ExxonMobil, 2018). Therefore, for integrated oil companies a rough approximation of 50% of emissions from upstream and 50% of emissions from downstream was carried forward into the Regional Activity Conversion Factor (RACF) calculation; however for companies not listed as integrated the weighting was 100% on the upstream (production) side (see below).

Gathering Company Total Emissions Data

Emissions data proved considerably more challenging to find than for the economic indicators of success. Though most large companies now record and report emissions by gas type, this trend was not pervasive prior to 2005-2006 and remains less consistent for small cap companies even in 2017. Carbon dioxide emissions across the entire company were typically the most widely reported across all companies, with 12 of the 20 NYSE listed CLaSLCs and 8 of the 20 LSE listed CLaSLCs reporting data across years spanning multiple phases of the EU ETS. Detailed carbon dioxide emissions data were also reported by all 3 DLCs (BP, Shell and Total). Methane and nitrous oxide emissions proved less well reported than for carbon dioxide however it was still possible to generate datasets for both emissions types. All 3 DLCs reported methane and nitrous oxide emissions across the whole company for the same periods in which carbon dioxide emissions were reported. Whereas ten NYSE listed CLaSLCs and four LSE listed CLaSLCs and nine NYSE listed CLaSLCs and five LSE listed CLaSLCs reported annualized data for total company nitrous oxide and methane emissions, respectively.

Extrapolating Company Regional Emissions from Gathered Total Emissions Data

No companies report annual emissions by geographic segment. Therefore, the RACF was developed and used to convert the total annual company emissions into regional emissions which were reflective of the given company's operations within a specific region (either in Europe or in the U.S. in the case of this analysis).

The formula for calculating the RACF was dependent upon whether the company in question was integrated or focused mainly on upstream operations and the availability of data. In the case of producers the formula was as follows:

Equation 2:

$$RACF_P = \frac{Production_R}{Production_T}$$

The formula for calculating the RACF for integrated producers was as follows:

Equation 3:

$$RACF_I = 0.5 * \frac{Production_R}{Production_T} + 0.5 * \frac{Refining\ Capacity_R}{Refining\ Capacity_T}$$

$RACF_P = RACF\ for\ pure\ upstream\ companies$

$RACF_I = RACF\ for\ integrated\ companies$

$Production_R = Production\ in\ region\ of\ interest\ (Europe\ or\ U.S.)$

$Production_T = Total\ company\ production$

$Refining\ Capacity_R = Refining\ capacity\ in\ region\ of\ interest\ (Europe\ or\ U.S.)$

$Refining\ Capacity_T = Total\ company\ refining\ capacity$

In the case of certain integrated companies downstream information was not published by geographic segment. These include Hess and Chevron. In these cases, where data were not available to calculate $RACF_I$ (see Equation 3) the RACF was calculated as if these integrated companies were producers (see Equation 2).

Through utilizing this method the intention was to account for both the production and refining processes monitored by the EU ETS and the processes which account for the emission of greenhouse gases within the oil and gas sector (see previous paragraph within this Section). In the case of DLCs, a RACF was assigned for both Europe and the U.S. in order to conduct comparable analysis between both regions for all three companies. Whereas CLaSLCs received a single RACF dependent on whether they were listed on the NYSE and based in the U.S., hence were given a U.S. RACF, or listed on the LSE and based in Europe, hence were given a Europe RACF. Upon calculation of the RACF for each company annually, the total company annual emissions recorded from company reports were multiplied by this RACF to produce an approximation for regional emissions from each gas type.

SECTION 3.3: PRIMARY DATA ANALYSES

Section 3.3.1: Overall Correlation between Economic Performance and Emissions

Early stage analysis focused on the correlation between three indicators of economic success (ROE, Annual Rate of Change in Total Net Income and Annual Rate of Change in Regional Net Income) (see Section 3.2) and the annual rate of change in total and regional company emissions over the course of the analysis period 2000-2017. All correlation coefficients were calculated for each DLC and CLaSLC across the analysis period for carbon dioxide, nitrous oxide and methane, with two coefficients calculated for each gas for each DLC (one for the Europe region and one for the U.S.). However, correlations were not calculated using ROE or Total Net Income for DLCs as these values are the same across the entire company; the only difference for DLCs is reflected in regional emissions and Regional Net Income. The coefficients from this analysis address the hypothesis that the overall correlations between economic performance and the annual rate of change in the emissions of monitored gases over the course of the EU ETS (2005-2017) will be more negative for European operators than for U.S. operators (see Section 2.2).

Section 3.3.2: Incremental Correlation between Economic Performance and Emissions

The same process as described above was repeated incrementally for each company across each phase of the EU ETS (see Section 1.2.1), and a 4 year period prior to its initiation. This was conducted in order to address the hypothesis that the incremental correlations between economic performance and annual rate of change in the emissions of monitored gases will become increasingly negative through each phase of the EU ETS for European operators while there should be little change for U.S. operators (see Section 2.2).

SECTION 3.4: SUPPORTING DATA ANALYSES

Section 3.4.1: T-Tests on Overall Correlations

One tailed t-tests were conducted on the sets of correlations between each indicator of economic success and each emission type calculated as part of the analysis discussed in Section 3.3.1. In testing the hypothesis that the overall correlations between economic performance and the annual rate of change in the emissions of monitored gases over the course of the EU ETS (2005-2017) will be more negative for European operators than for U.S. operators, it was imperative to ensure that the European and U.S. results could be differentiated with statistical significance. Working under the hypothesis that the correlation coefficients should be more negative for European than U.S. operators, one tailed t-tests were interpreted to be the most efficient way of identifying the degree of significance for which this could be concluded. Consistent with the hypothesis:

- European DLCs and CLaSLCs will display a more negative correlation coefficient between the annual change in carbon dioxide emissions and indicators of economic success than their U.S. counterparts with a high degree of statistical significance.

- European DLCs and CLaSLCs will display a more negative correlation coefficient between the annual change in nitrous oxide emissions and indicators of economic success than their U.S. counterparts with a moderate to high degree of statistical significance. The disparity between European and U.S. correlation coefficients should be less for nitrous oxide than for carbon dioxide given its later inclusion within the scheme.
- European DLCs and CLaSLCs will not display a correlation coefficient between the annual change in methane emissions and indicators of economic success that is different than their U.S. counterparts with any statistical significance given that the EU ETS does not reference methane emissions explicitly.

One tailed t-tests were used as the hypotheses to be tested reflect an expected relationship: that European operators should have more negative correlations between their annual change in monitored emissions and economic success than their U.S. counterparts. However, given the minimal number of years within each phase of the EU ETS, and therefore the limited availability of data points within each phase, t-tests were only conducted on overall correlations, which span the entirety of the EU ETS, and not on incremental correlations.

Chapter 4: Results

Section 4.1: Results of Primary Analysis

Section 4.1.1: Overall Correlation between Economic Performance and Emissions

Across the entirety of the analysis period 2000 through 2017 it is clear that there is little disparity in the economic performance exhibited by European DLCs and CLaSLCs and their U.S. counterparts, less so than was postulated in Section 2 (see Appendix A for raw data, Appendix B for correlation coefficients and Appendix C for plots of raw emissions data).

As noted in Section 2.2, companies, or portions of DLCs, operating within the jurisdiction of the EU ETS were hypothesized to have an overall more negative correlation between ROE and Total Net Income and total annual carbon dioxide emissions and between Regional Net Income and carbon dioxide emissions than U.S. companies. This did not prove to be the case, particularly in the case of CLaSLCs (see Appendix B.3). Similarly, companies, or portions of DLCs, operating within the jurisdiction of the EU ETS were hypothesized to have an overall more negative correlation between economic performance and nitrous oxide emissions. This trend was more pronounced in the CLaSLC datasets compared with DLCs. Additionally, the annual change in methane emissions showed the strongest negative correlation with European economic performance (contrary to the hypothesis stated in Section 2.2). Again, this trend was most prominent for CLaSLCs, but was also present for DLCs (see Appendix B.3).

By considering the raw data plotted in Appendix C alongside the total correlation coefficients between emissions and economic performance (see Appendix B.3) it is possible to better interpret the overall correlations identified. With regards to DLCs, emissions of nitrous oxide and methane were dropping significantly prior to the introduction of the EU ETS in 2005 and then stagnated through the 2005 to 2017 period. Carbon dioxide emissions decreased steadily over the 2000 to 2017 period for DLCs though generally at a slower rate after the introduction of the EU ETS in 2005. The stabilizing of DLC emissions through the 2005 to 2017 period aligns with the broad trend recorded in Figure 2.1, lending credit to the interpretation that the European segment of DLCs may have suffered poorer economic performance, resultant from penalties incurred from exceeding allowances, partly as a result of a failure to further reduce monitored emissions in Europe. However, this is not apparent within the correlations noted for the European segments of DLCs versus their U.S. counterparts across the entirety of the EU ETS. Additionally, European and U.S. CLaSLCs also do not display a significant reduction in monitored emissions across the EU ETS period (2005 to 2017). However, European CLaSLCs weakly display a more negative correlation between regional net income and regional carbon dioxide emissions than their U.S. equivalents. The lack of significant reductions in monitored emissions over the course of 2005 to 2017 in both CLaSLC datasets (see Figures C.4 through C.9) and the more negative correlation between carbon dioxide emissions and economic performance for European CLaSLCs suggests that this may due to a flattening of annual emissions and poor economic performance.

Section 4.1.2: Temporal Variation in the Correlations between Economic Performance and Emissions

The incremental correlations (see Section 3.3.2) calculated generally followed a similar trend as the overall correlations noted in Section 4.1.1. However, an increasingly negative correlation between carbon dioxide emissions and economic performance was not present within either of the European datasets (see Figures 4.1, 4.2, 4.3 and 4.4). The correlation between economic performance and the annual change in nitrous oxide emissions was also inconsistent with that hypothesized in Section 2.2 for both DLCs and CLaSLCs. From Phase II onward the correlation coefficient for European operators becomes increasingly negative relative to their U.S. counterparts (see Figures 4.5, 4.6, 4.7 and 4.8), supporting the hypothesis of this study. Incremental correlations between the annual change in methane emissions and economic performance showed the greatest initial variation within U.S. and European datasets. European CLaSLCs show an increasingly negative correlation between economic performance and methane emissions (as did U.S. DLCs). However European portions of DLCs and U.S. CLaSLCs did not generally display a consistent temporal trend in the correlation between methane emissions and economic performance (see Figures 4.9, 4.10, 4.21 and 4.12). The incremental correlations for methane broadly support the hypothesis of Section 2.2 that the correlations between methane emissions and economic performance would be similar for U.S. and European operators. However, the conclusion is similar for carbon dioxide, with nitrous oxide being the only monitored emissions to fit the incremental hypothesis made in Section 2.

The increasingly negative correlation between nitrous oxide emissions and regional economic performance for European operators after Phase II of the EU ETS is associated with no clear reduction in nitrous oxide emissions (see Appendix C). This suggests that an increasingly negative correlation between emissions and economic performance is the result of decreasing economic performance. This increasingly negative correlation is therefore interpreted to be the result of stable nitrous oxide emissions (apart from Cairn Energy) and poorer economic performance. Carbon dioxide and methane emissions also do not show a clear reduction over the course of the EU ETS however, an increasingly negative correlation between European operators' regional economic performance and their carbon dioxide and methane emissions versus their U.S. counterparts is not as apparent as for nitrous oxide. It is inferred that this may partly be a result of methane's lack of inclusion under the scope of the EU ETS and therefore relatively stable methane emissions are not subject to increasing penalty under the scheme. In turn this does not result in decreased economic performance and therefore would not result in an increasingly negative correlation between regional methane emissions and regional economic performance in Europe.

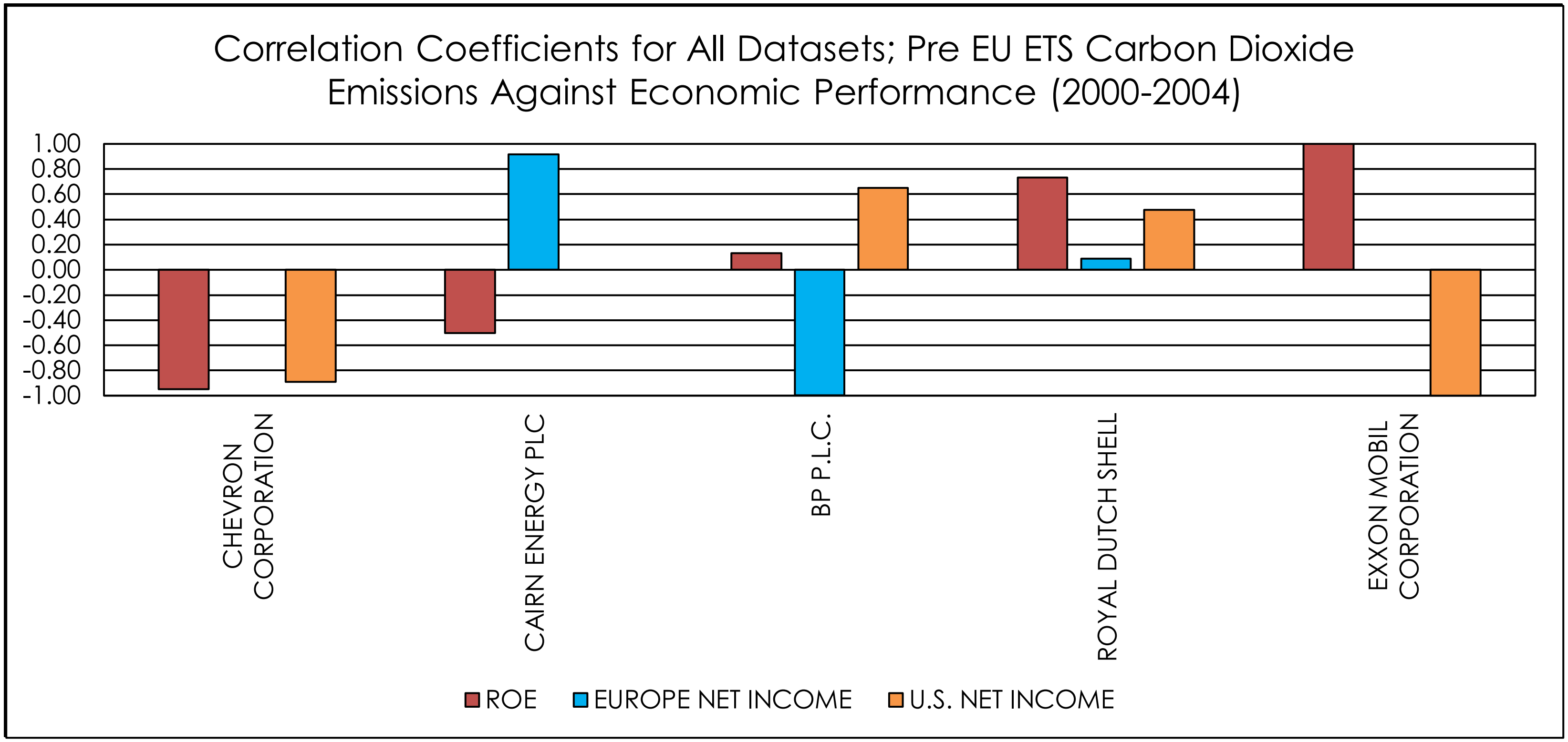

Figure 4.1: Correlation coefficients for all data sets for the period 2000 through 2004 for carbon dioxide emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note that a lack of data during the 2000 to 2004 period (prior to the EU ETS) does not allow for robust inferences

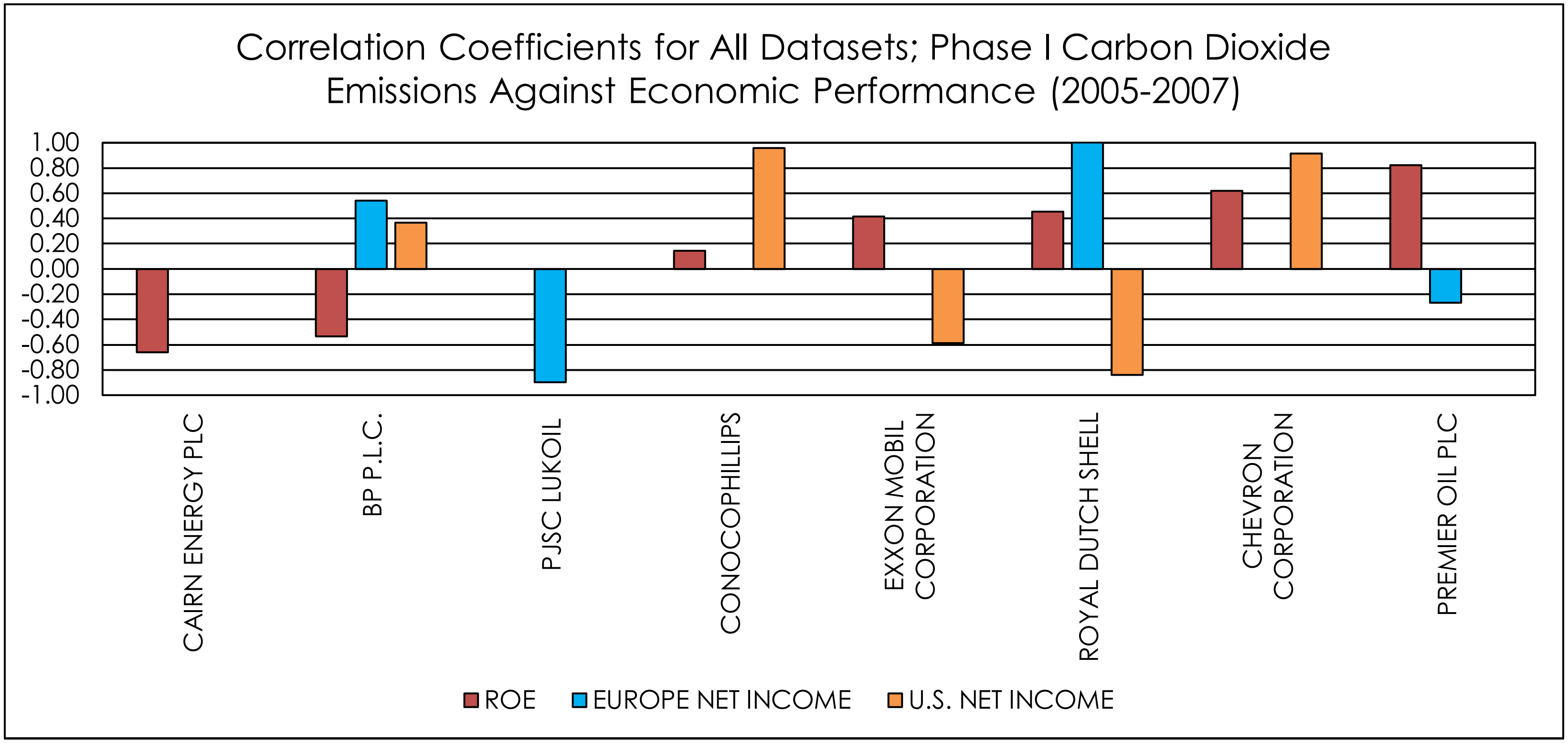

Figure 4.2: Correlation coefficients for all data sets for the period 2000 through 2004 for carbon dioxide emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note a higher proportion of U.S. companies with a negative correlation between regional carbon dioxide emissions and economic performance.

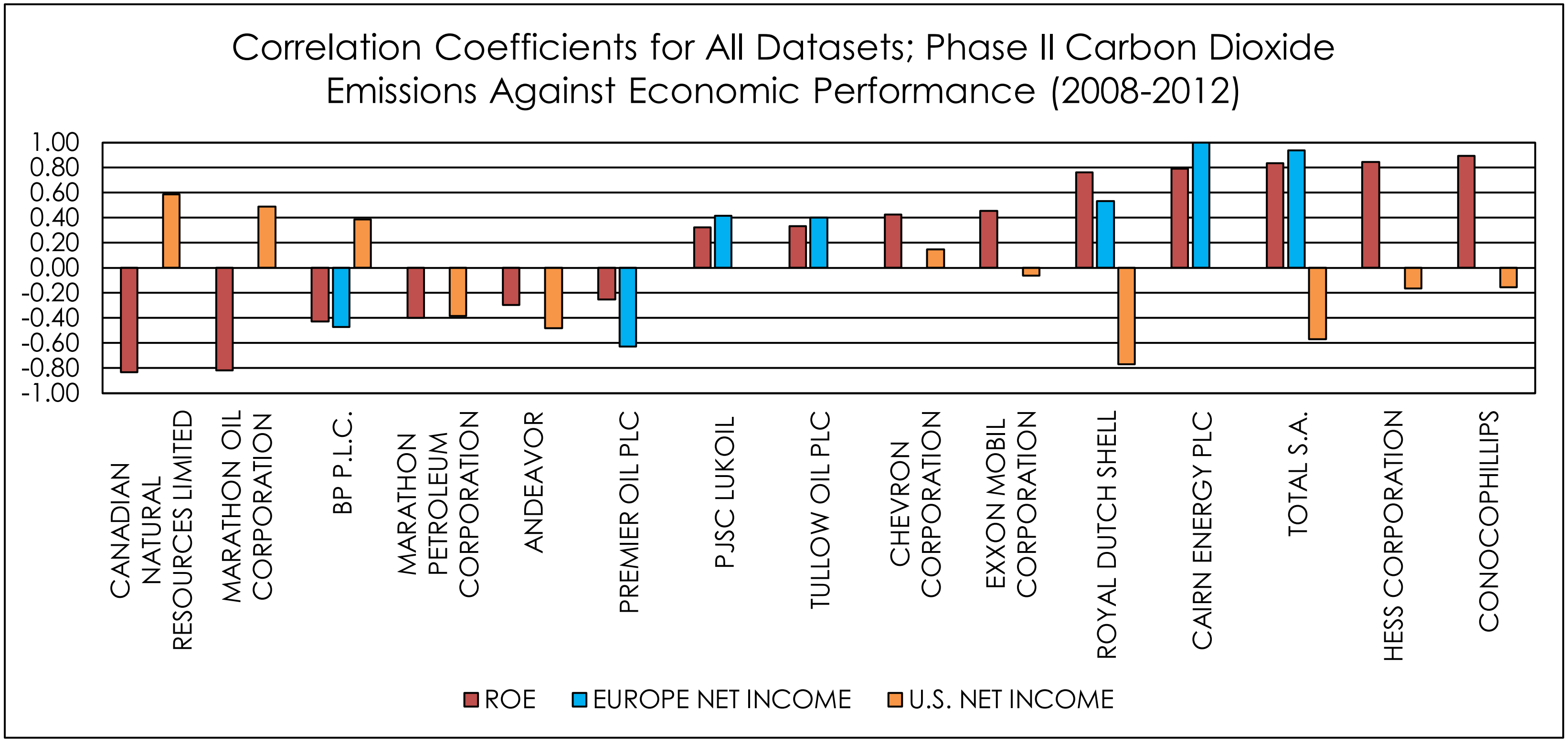

Figure 4.3: Correlation coefficients for all data sets for the period 2008 through 2012 for carbon dioxide emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note a higher proportion of U.S. companies with a negative correlation between regional carbon dioxide emissions and economic performance.

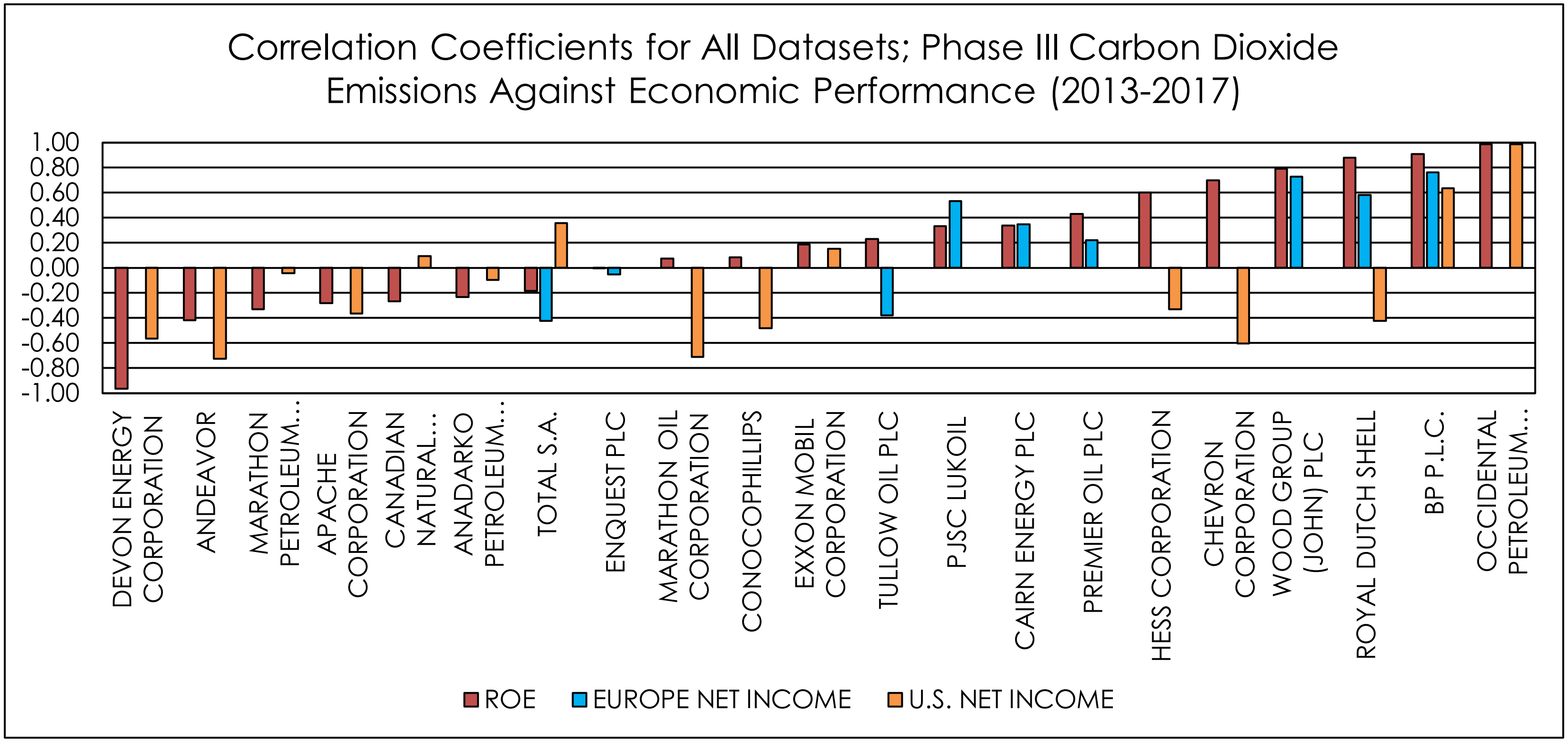

Figure 4.4: Correlation coefficients for all data sets for the period 2013 through 2017 for carbon dioxide emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note again a higher proportion of U.S. companies with a negative correlation between regional carbon dioxide emissions and economic performance.

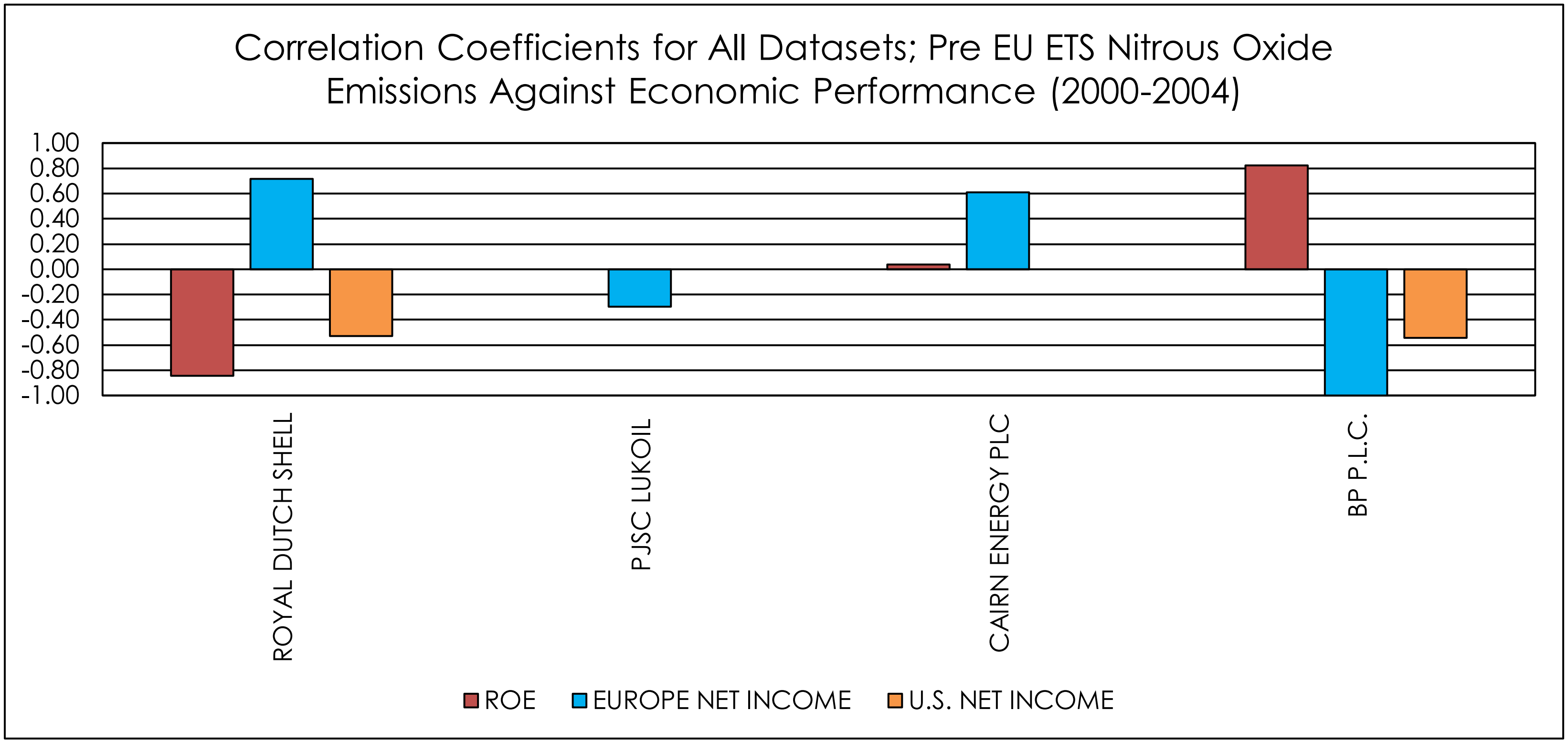

Figure 4.5: Correlation coefficients for all data sets for the period 2000 through 2004 for nitrous oxide emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note that a lack of data during the 2000 to 2004 period (prior to the EU ETS) does not allow for robust inferences.

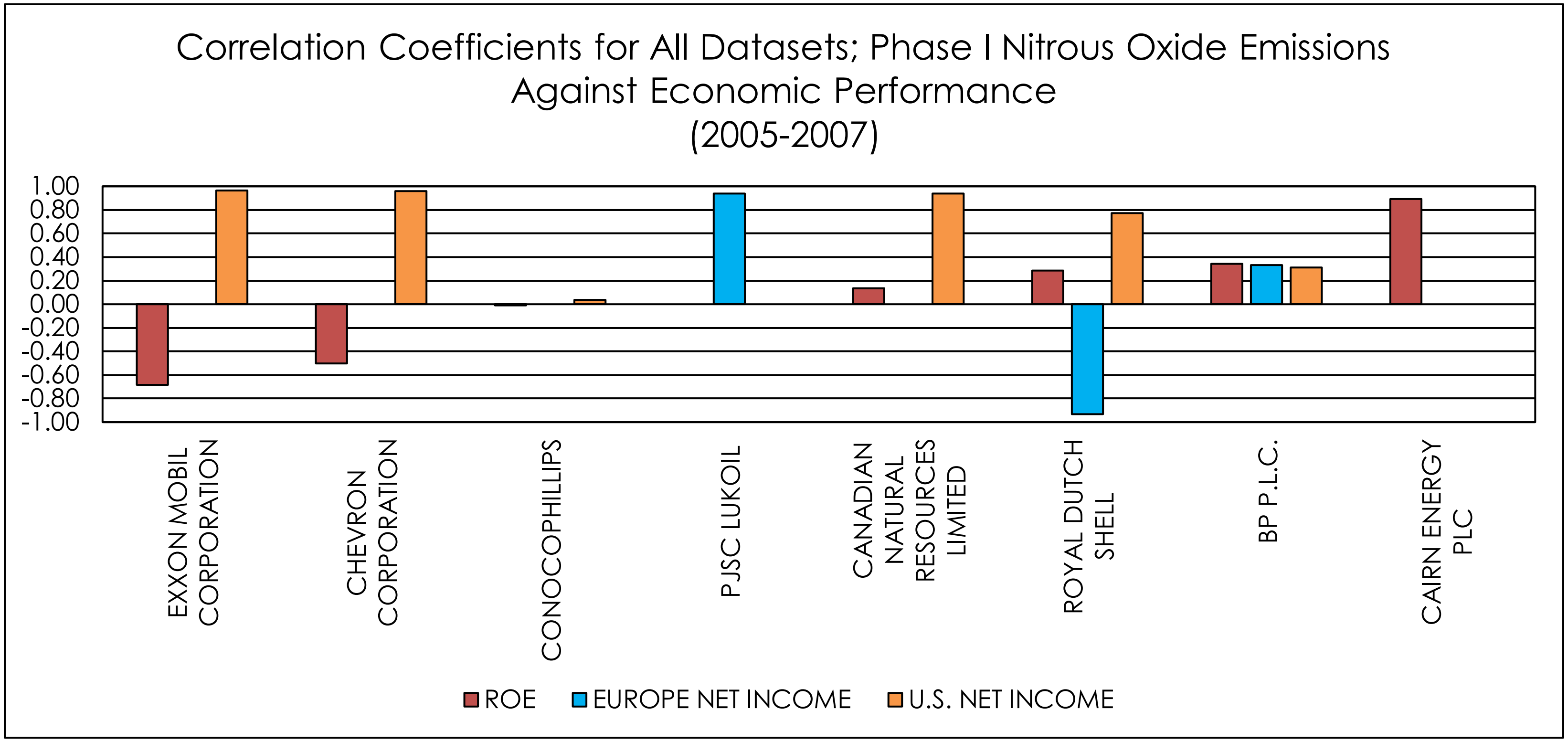

Figure 4.6: Correlation coefficients for all data sets for the period 2005 through 2007 for nitrous oxide emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note a greater proportion of European. companies with a negative correlation between regional nitrous oxide emissions and regional economic performance prior to the monitoring of nitrous oxide by the EU ETS.

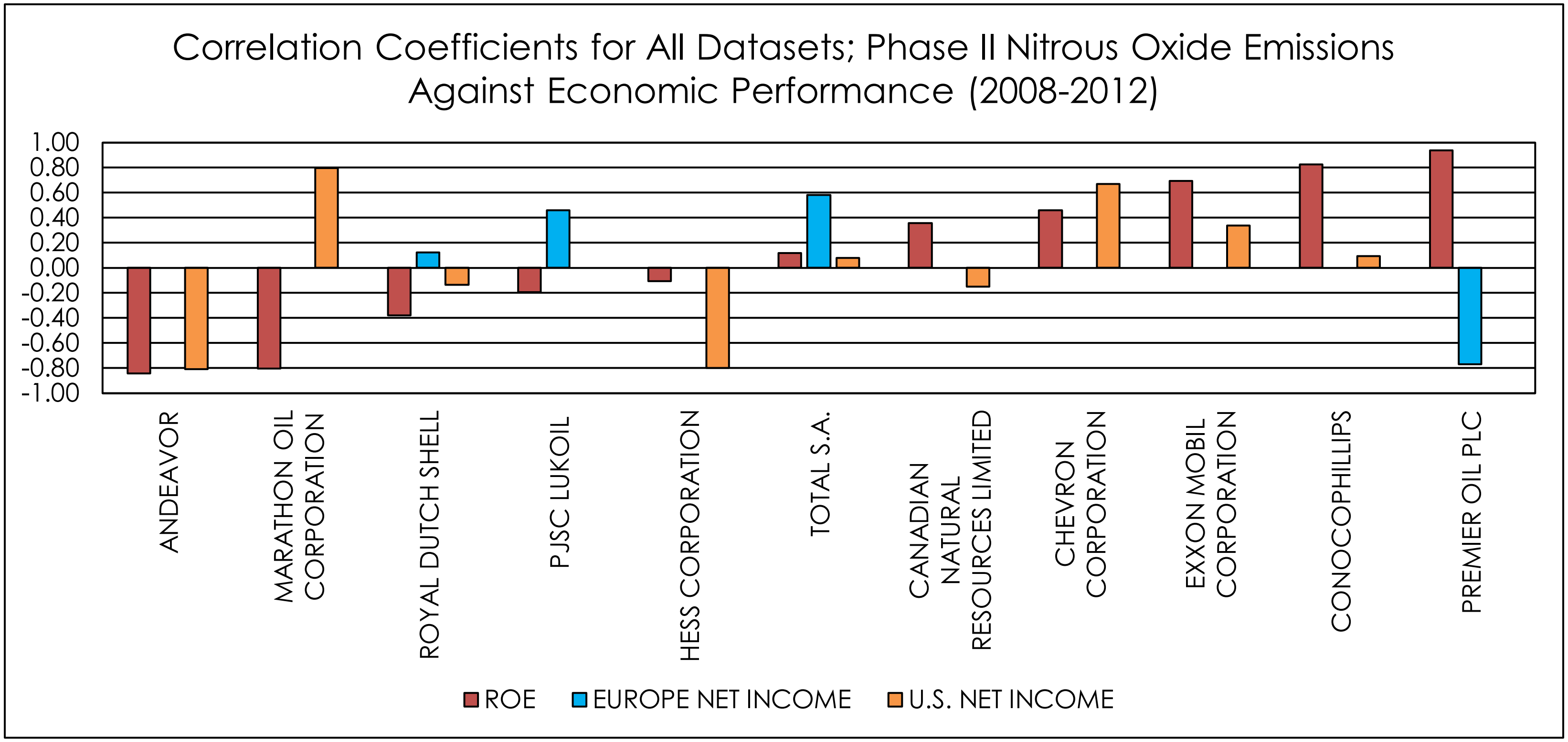

Figure 4.7: Correlation coefficients for all data sets for the period 2008 through 2012 for nitrous oxide emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note a greater proportion of U.S. companies with a negative correlation between regional nitrous oxide emissions and regional economic performance during the first phase of the monitoring of nitrous oxide by the EU ETS.

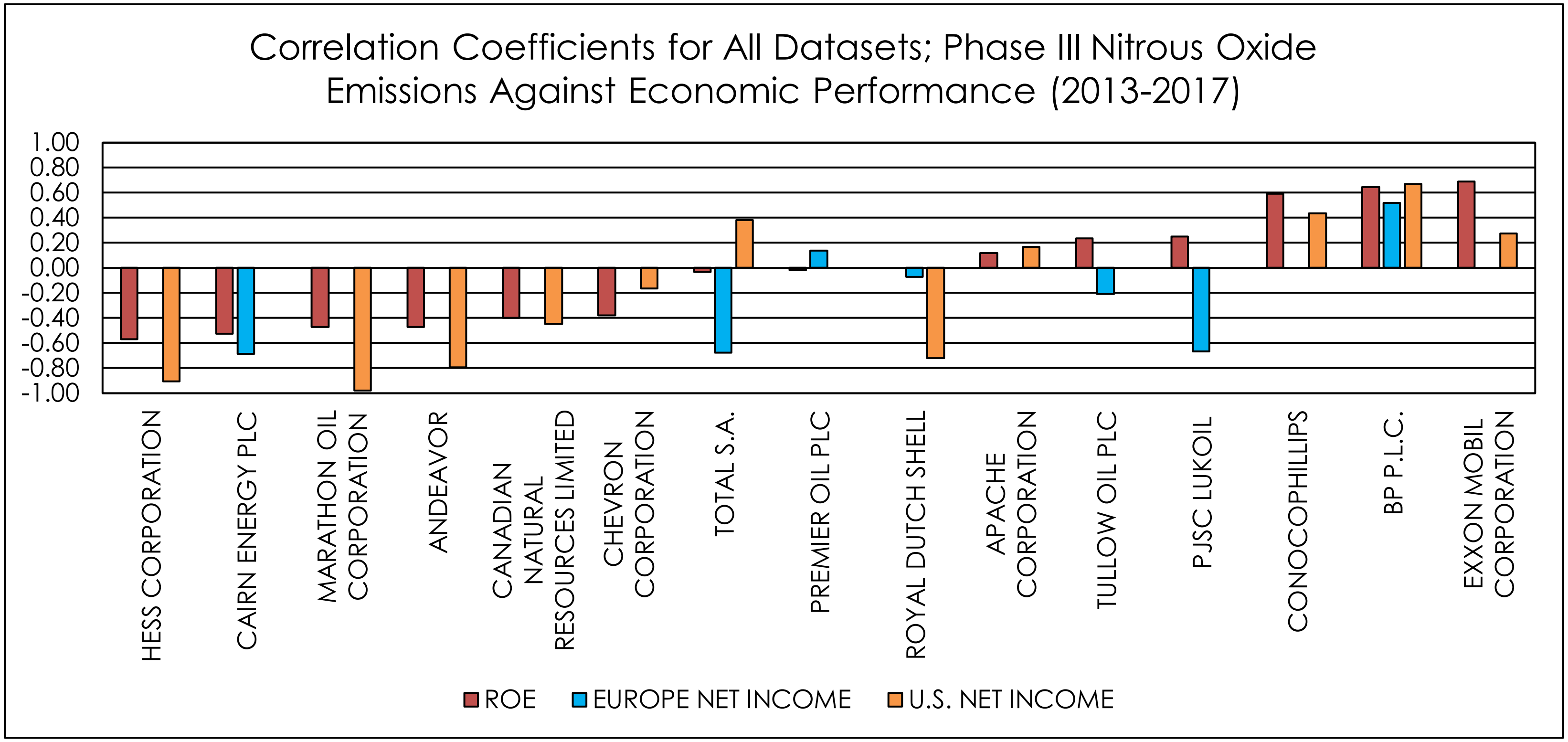

Figure 4.8: Correlation coefficients for all data sets for the period 2013 through 2017 for nitrous oxide emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note that over time a greater proportion of European companies now have a negative correlation between regional nitrous oxide emissions and regional economic performance.

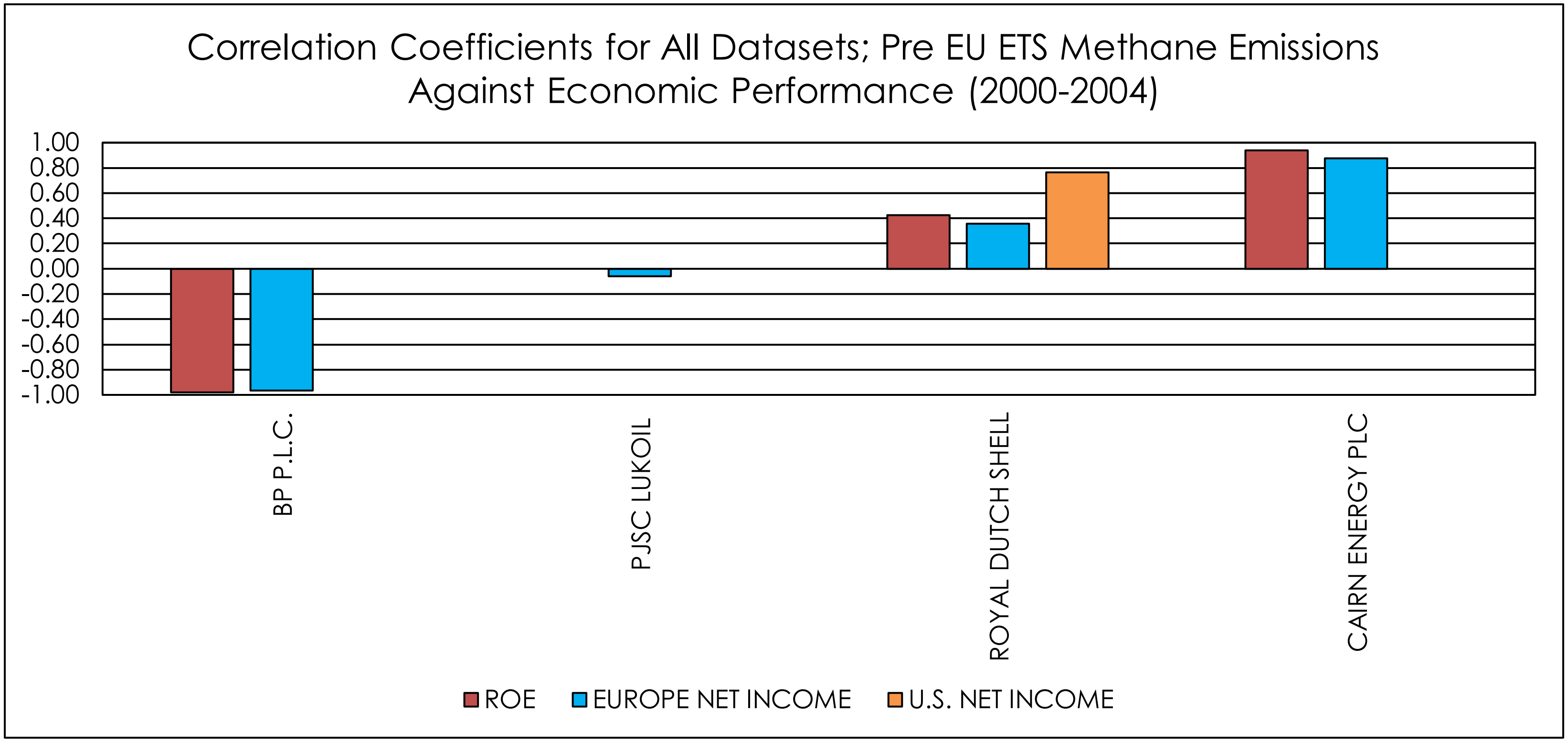

Figure 4.9: Correlation coefficients for all data sets for the period 2000 through 2004 for methane emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note that a lack of data during the 2000 to 2004 period (prior to the EU ETS) does not allow for robust inferences, though European operators show a more significant negative correlation between methane emissions and regional net income.

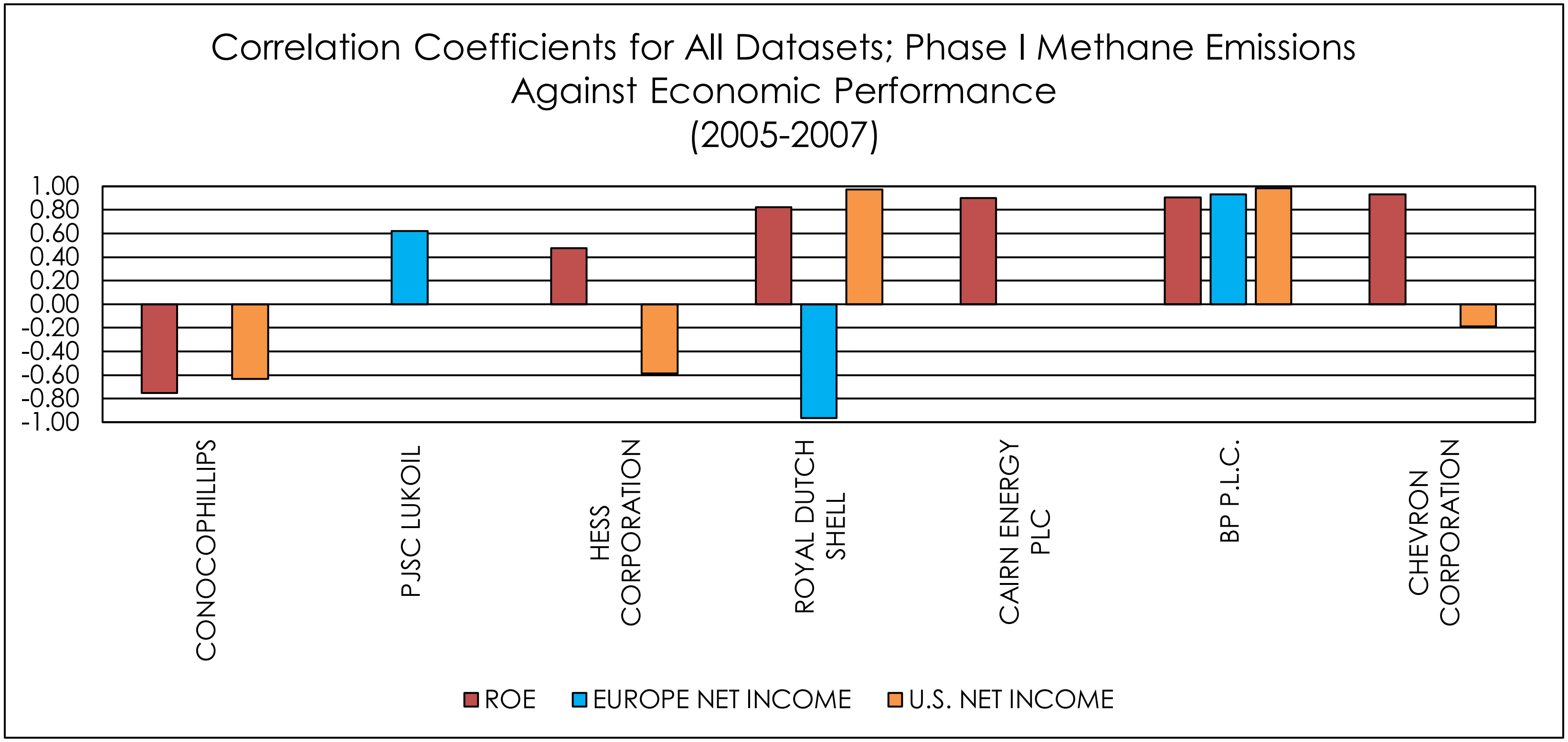

Figure 4.10: Correlation coefficients for all data sets for the period 2005 through 2007 for methane emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note a relatively even proportion of European and U.S. companies with a negative correlation between regional methane emissions and regional economic performance. Methane is unmonitored during Phase I of the EU ETS.

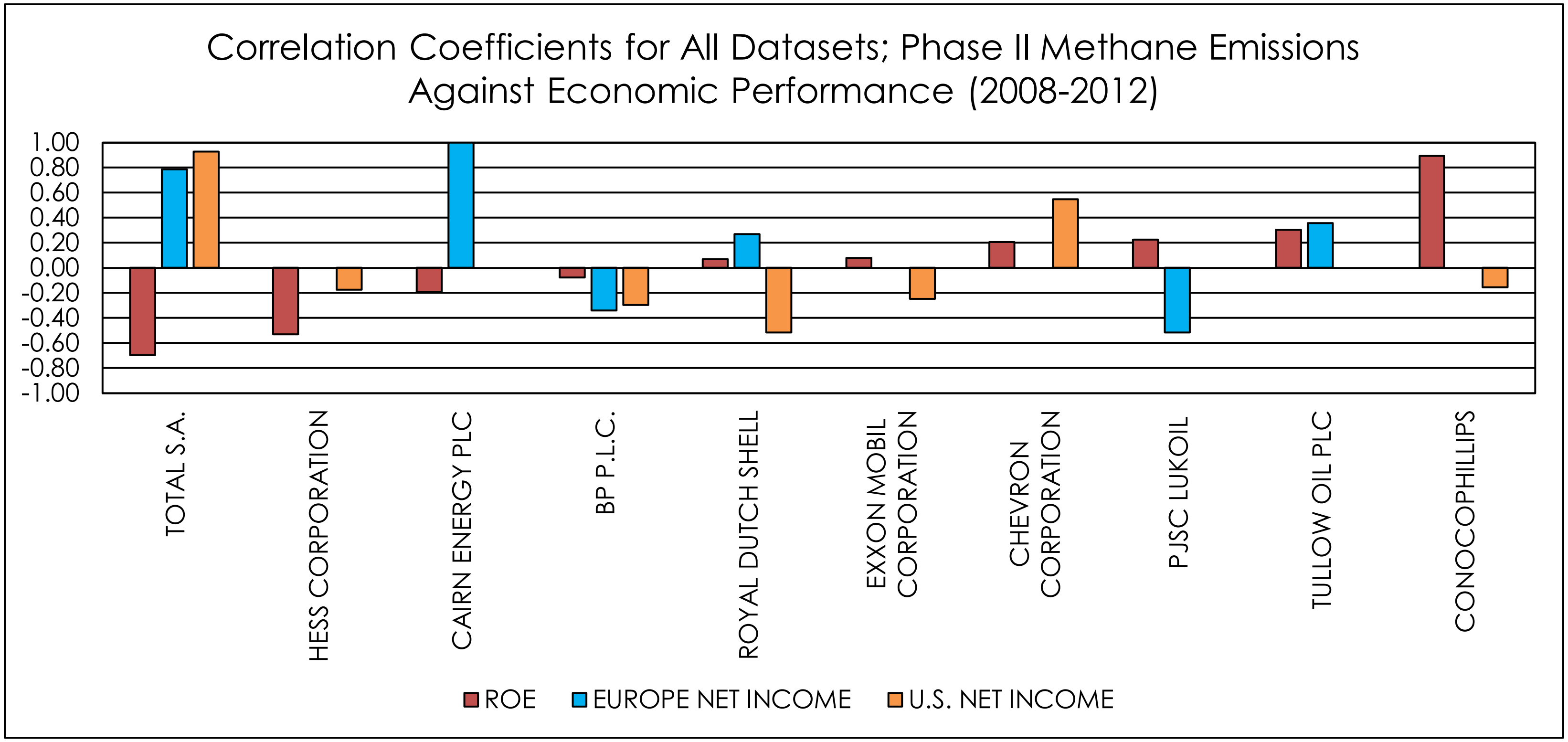

Figure 4.11: Correlation coefficients for all data sets for the period 2008 through 2012 for methane emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note a relatively even proportion of European and U.S. companies with a negative correlation between regional methane emissions and regional economic performance. Methane is unmonitored during Phase II of the EU ETS.

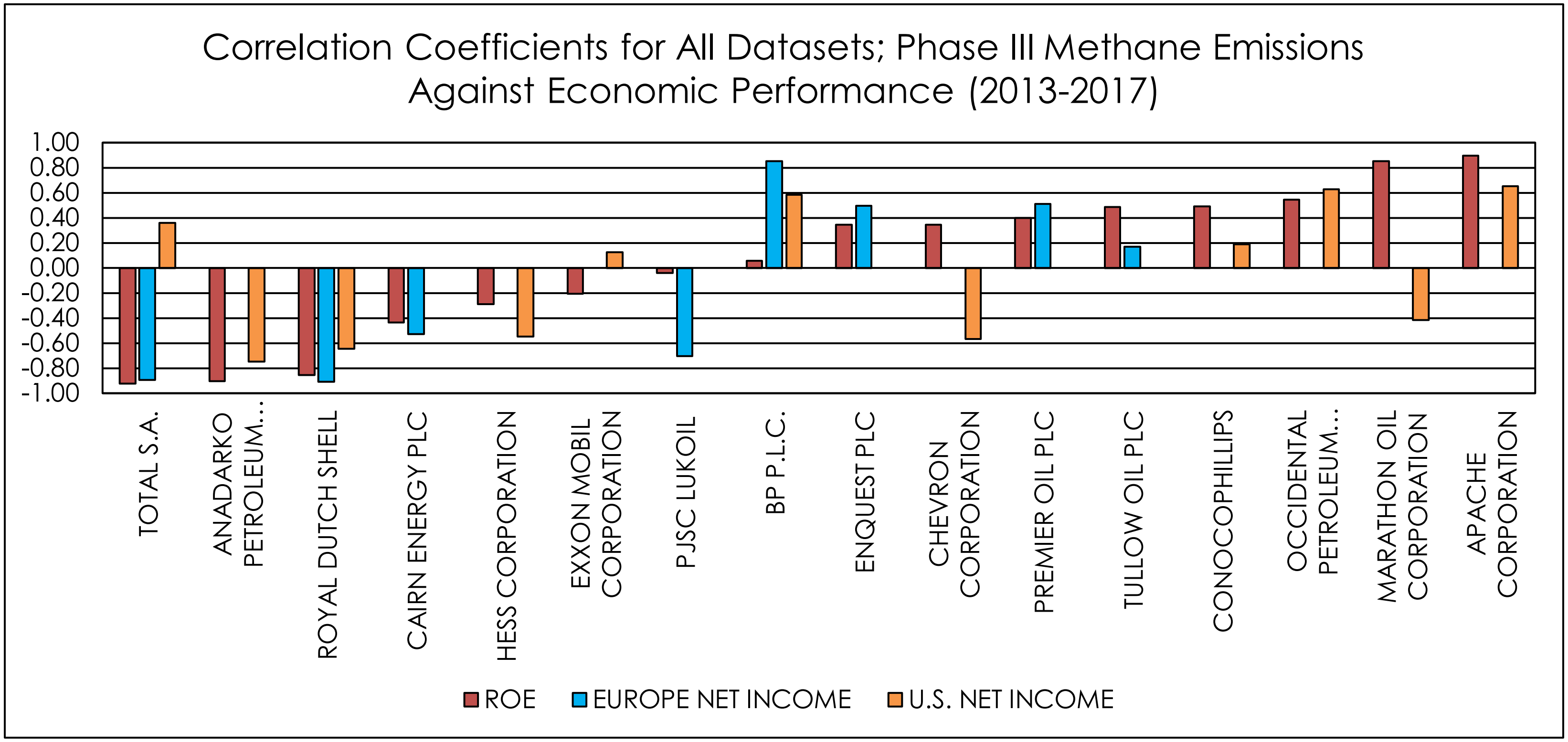

Figure 4.12: Correlation coefficients for all data sets for the period 2103 through 2017 for methane emissions against economic performance (ROE and Regional Net Income). See Appendix A for raw data and Appendix B for tables of correlation coefficients. Note the relatively even proportion of European and U.S. companies with a negative correlation between regional methane emissions and regional economic performance. Methane is unmonitored during Phase III of the EU ETS.

Section 4.2: Results of Supporting Analysis

Section 4.2.1: T-Tests on Overall Correlations

The t-test was used to assess the statistical significance of the overall correlations between emissions and economic performance for European versus U.S. operators (see Section 3.4). Through utilizing one-tailed t-tests the intention was to identify whether the correlations between economic performance and annual changes in emissions were more negative for operators under the EU ETS than their equivalents outside of the scheme (the U.S. comparison groups).

T-tests generate p-values between 0 and 1, based on the degree of statistical significance that two sample groups are statistically different, in this case whether European datasets show more negative correlations between economic performance and annual changes in emissions than their U.S. equivalents. The p-value generated is reflective of the degree of confidence with which the hypothesis can be affirmed. T-tests were conducted on the European portion of DLCs versus the U.S. portion of DLCs and European CLaSLCs versus U.S. CLaSLCs with the results displayed in Tables 4.1 and 4.2. Correlations between the Regional Net Income and methane emissions for CLaSLCs proved the most statistically different between European and U.S. operators, with 98% confidence (the same was true for DLCs at 88% confidence). Additionally, a statistical difference between Regional Net Income and regional nitrous oxide emissions was concluded with 88% confidence for European versus U.S. CLaSLCs.

	ROE	Total Net Income	Regional Net Income
Carbon Dioxide	N/A	N/A	0.35
Nitrous Oxide	N/A	N/A	0.50
Methane	N/A	N/A	0.12

Table 4.1: P-values for t-tests conducted on correlation between emissions (in left column) and indicators of economic performance (in top row) for European versus U.S. portions of DLCs. Note the p-value of 0.12 suggesting with 88% confidence that European portions of DLCs display a more negative correlation between regional methane emissions and regional net income than their U.S. counterparts.

	ROE	Total Net Income	Regional Net Income
Carbon Dioxide	0.46	0.32	0.12
Nitrous Oxide	0.16	0.32	0.31
Methane	0.21	0.16	0.02

Table 4.2: P-values for t-tests conducted on correlation between emissions (in left column) and indicators of economic performance (in top row) for European versus U.S. CLaSLCs. Note the p-value of 0.12 suggesting with 88% confidence that European CLaSLCs display a more negative correlation between regional nitrous oxide emissions and regional net income than their U.S. counterparts. Also note the p-value of 0.02 suggesting with 98% confidence that European CLaSLCs display a more negative correlation between regional nitrous oxide emissions and regional net income than their U.S. counterparts.

Chapter 5: Discussion

Section 5.1: Summary of Key Results

From the results addressed in Section 4 it is apparent that there are some statistical differences in the correlations between economic performance and annual changes in gaseous emissions for oil and gas producers and refiners operating under the jurisdiction of the EU ETS compared with those operators which are not subject to this jurisdiction. Section 1 outlined the basic premise of the EU ETS: to encourage a reduction in emissions without significantly damaging the economic performance of operators under the purview of the scheme (Convery, 2009; Skjaerseth and Wettestad, 2009). Results presented in Section 4 infer that oil and gas producers and refiners under the EU ETS typically experience poorer economic performance, an approximately 7% poorer ROE than the NYSE dataset, however presently it remains unclear as to whether these differences are the direct result of a stagnation of European operator emissions and a lowering of EU ETS emissions allowances (see Figure 3.1) or they occurred as result of external factors (see Sections 2.3 and 5.2).

Trends in carbon dioxide emissions did not reflect those hypothesized, supporting the existence of these external factors. Overall correlations between the annual rates of change in carbon dioxide emissions and economic performance did not generally show a more negative trend for European operators than their U.S. counterparts (see Figures 5.1 and 5.2).

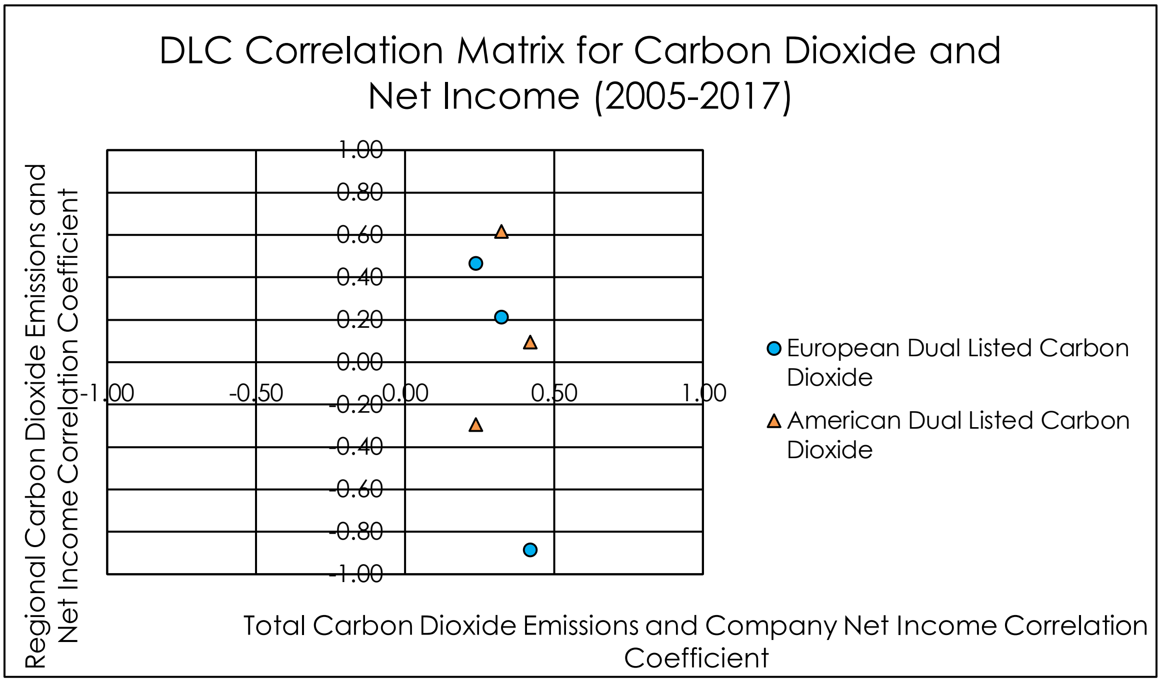

Figure 5.1: Correlation coefficients of total/regional carbon dioxide emissions against total/regional net income for DLCs. See Section 3.3.1 for description of the method behind this figure and Part 2 of the Bibliography for list of the raw data sources. Note that there is very little to distinguish the trends displayed by European and U.S. portions of DLCs.

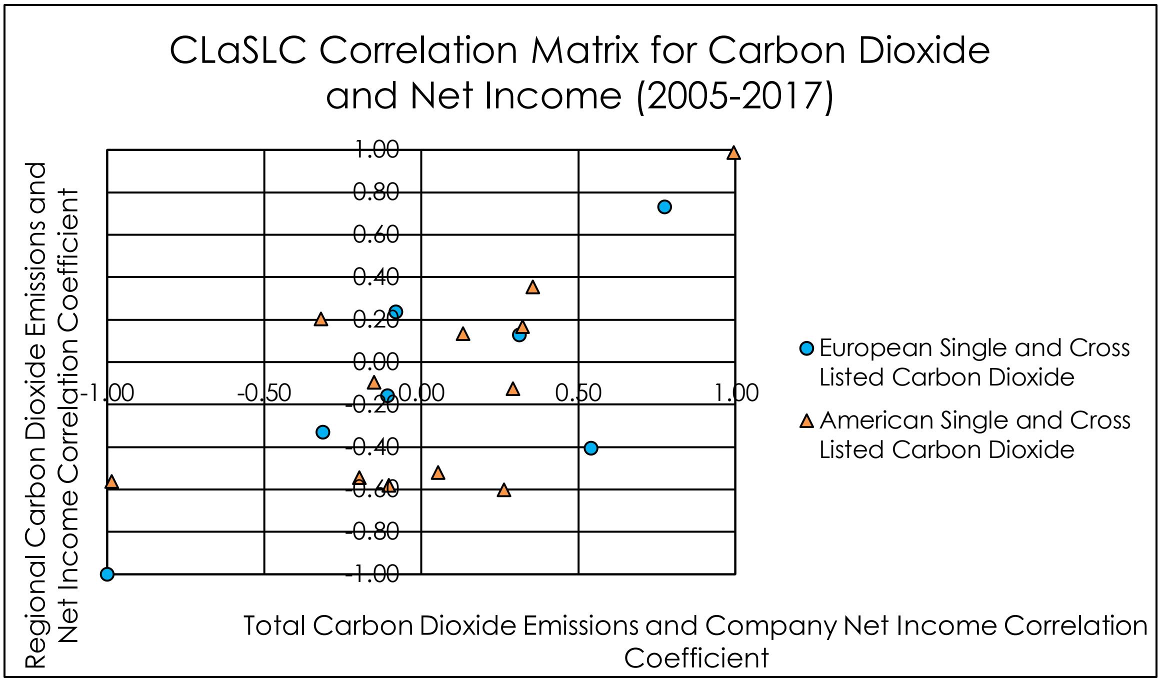

Figure 5.2: Correlation coefficients of total/regional carbon dioxide emissions against total/regional net income for CLaSLCs. See Section 3.3.1 for description of the method behind this figure and Part 2 of the Bibliography for list of the raw data sources. Note that, again there is little to distinguish European operators from their U.S. counterparts.

European segments of DLCs (n=3) and European CLaSLCs (n=6) also failed to show an increasingly negative correlation between regional carbon dioxide emissions and regional net income between Phase I and Phase III of the EU ETS relative to their U.S. counterparts (see Figure 5.3). U.S. operators also failed to show any significant trend in the correlations observed. Such a trend may result from the influence of external macroeconomic and commodity price factors which are not exclusive to the EU ETS (see Section 5.3) affecting the results. This is perhaps the reason for such insignificant statistical differences noted in Section 4.2 (see Section 3.4.1 and Section 4.2.1 for associated method and results). In all cases, results for carbon dioxide emissions therefore did not meet the initial hypothesis therefore inferring that global factors, external from the EU ETS may likely drive the trends noted in the correlations between economic performance and carbon dioxide emissions.

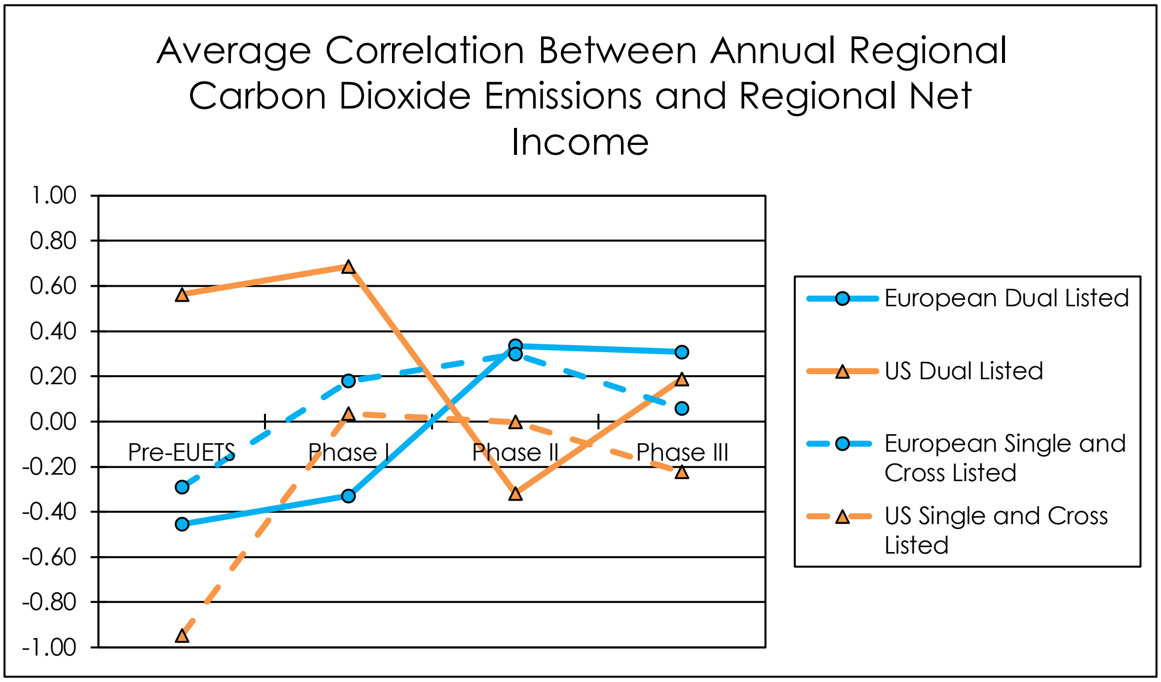

Figure 5.3: Average correlations between rates of change in regional net income and regional annual carbon dioxide emissions by phase of the EU ETS for European and U.S. CLaSLCs and the European and U.S. segments of DLCs. See Section 3.3.2 for description of the method behind this figure and Part 2 of the Bibliography for list of the raw data sources. Note that from Phase I onward, only U.S. CLaSLCs display an increasingly negative correlation.

Results for nitrous oxide emissions proved more conclusive than for carbon dioxide but were still generally insignificant. Overall correlations for the 2005-2017 conclude that, with 88% confidence, European CLaSLCs have a more negative correlation between economic performance and nitrous oxide emissions (see Figures 5.4 and 5.5). However, this is statistically insignificant. While incremental correlations (through each phase of the EU ETS) showed an increasingly negative correlation between nitrous oxide emissions and economic performance from Phase II of the EU ETS onward for European DLCs and CLaSLCs, though this trend was also present weakly within the U.S. CLaSLC dataset (see Figure 5.6).

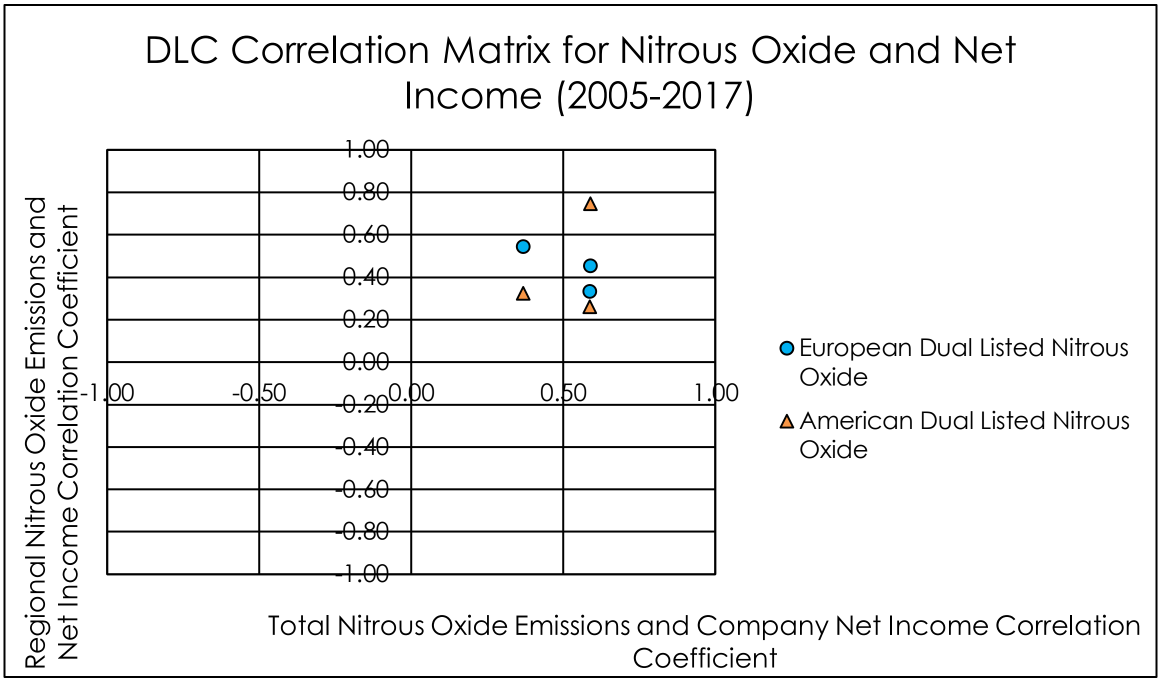

Figure 5.4: Correlation coefficients of total/regional nitrous oxide emissions against total/regional net income for DLCs. See Section 3.3.1 for description of the method behind this figure and Part 2 of the Bibliography for list of the raw data sources. Note that there is no clear difference in the correlations between nitrous oxide emissions and economic performance for the European versus the U.S. segments of DLCs.

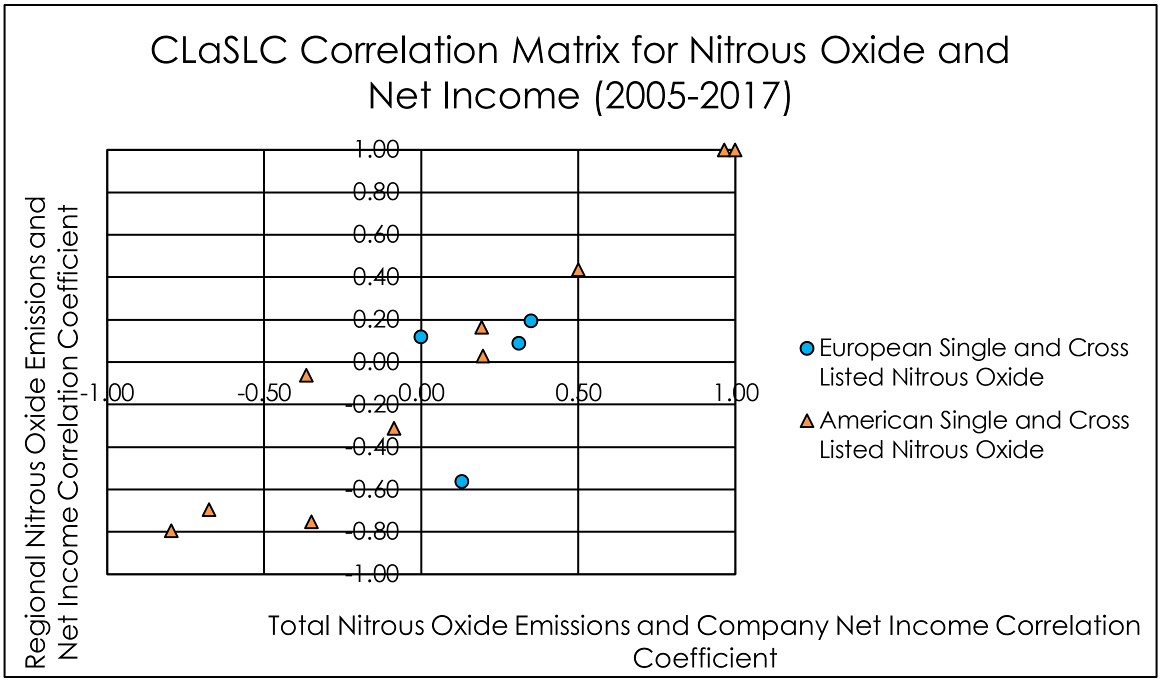

Figure 5.5: Correlation coefficients of total/regional nitrous oxide emissions against total/regional net income for CLaSLCs. See Section 3.3.1 for description of the method behind this figure and Part 2 of the Bibliography for list of the raw data sources. Note that there is no significant difference in the correlations between nitrous oxide emissions and economic performance for European CLaSLCs versus their U.S. counterparts.

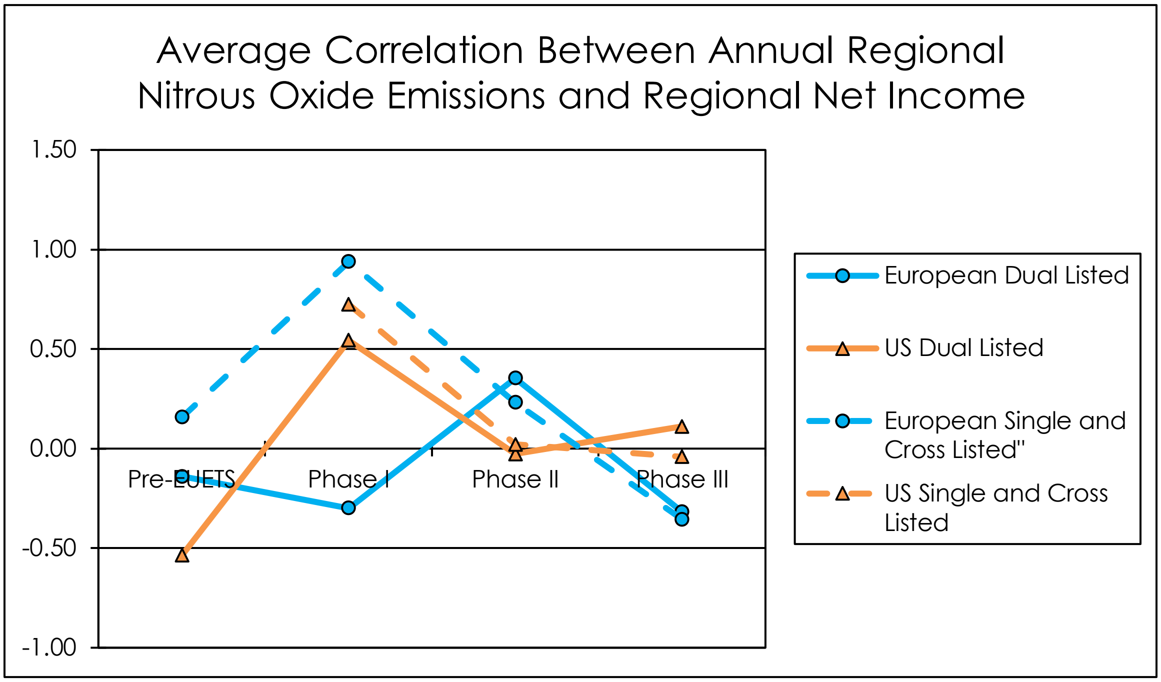

Figure 5.6: Average correlations between regional net income and regional nitrous oxide emissions by phase of the EU ETS for European and U.S. CLaSLCs and the European and U.S. segments of DLCs. See Section 3.3.2 for description of the method behind this figure and Part 2 of the Bibliography for list of the raw data sources. Note that from Phase II onward, the correlation between regional net income and nitrous oxide emissions trends generally more negative for European datasets versus their U.S. counterparts.

Given that methane emissions are not explicitly addressed by the EU ETS it was hypothesized that European and U.S. datasets would not display the difference in trends exhibited by the other emissions (see Section 2.2). It was therefore anticipated that trends exhibited with regards to methane would be more similar between European and U.S. datasets than for carbon dioxide and nitrous oxide. However this was not the case. European CLaSLCs showed a considerably more negative correlation between annual rate of change in methane emissions and economic performance than their U.S. counterparts, with 98% confidence; although results from DLCs were more aligned to the initial hypothesis (see Figures 5.7 and 5.8). Incremental correlations generally aligned with the initial hypothesis (see Section 2.2 and Figure 5.9). The incremental trend between regional economic performance and regional methane emissions did not follow a conclusive trend for the European versus U.S. company datasets and therefore were generally consistent with the initial hypothesis (see Section 2.2). The disparity in the overall correlations between economic performance and methane emissions for DLCs raises questions as to whether the method employed accounts for additional factors related to economic performance and emissions in the oil and gas sector (see Section 5.3).

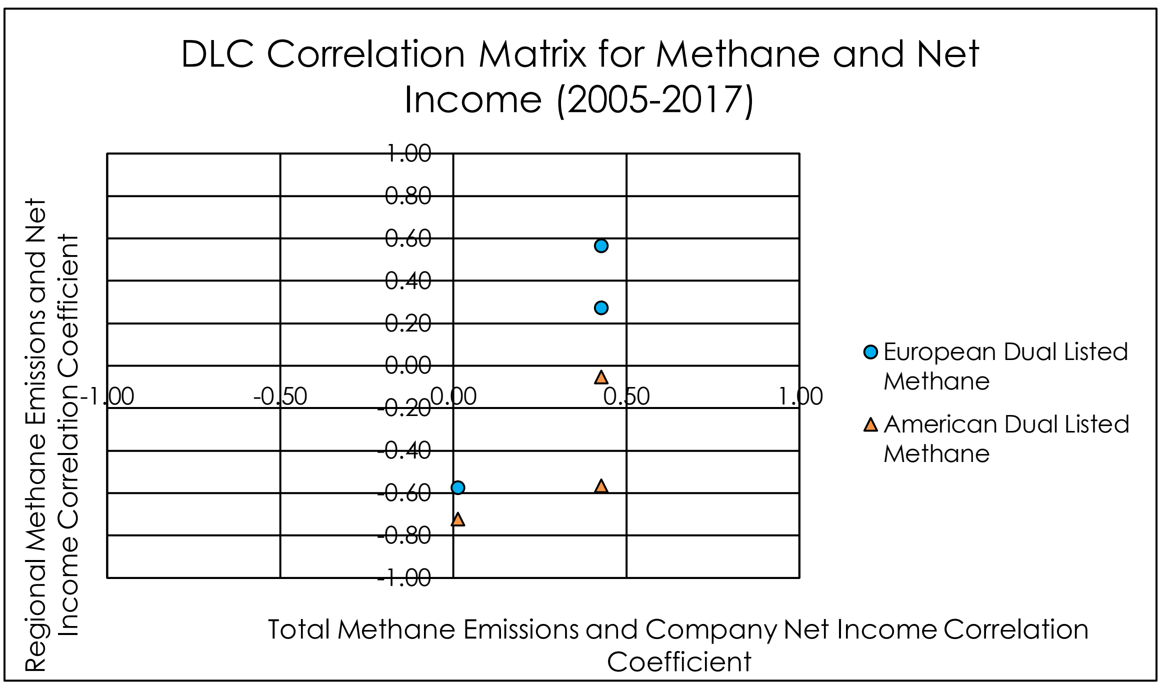

Figure 5.7: Correlation coefficients of total/regional methane emissions against total/regional net income for DLCs. See Section 3.3.1 for description of the method behind this figure and Part 2 of the Bibliography for list of the raw data sources. Note that there is little to distinguish the European from U.S. trend.

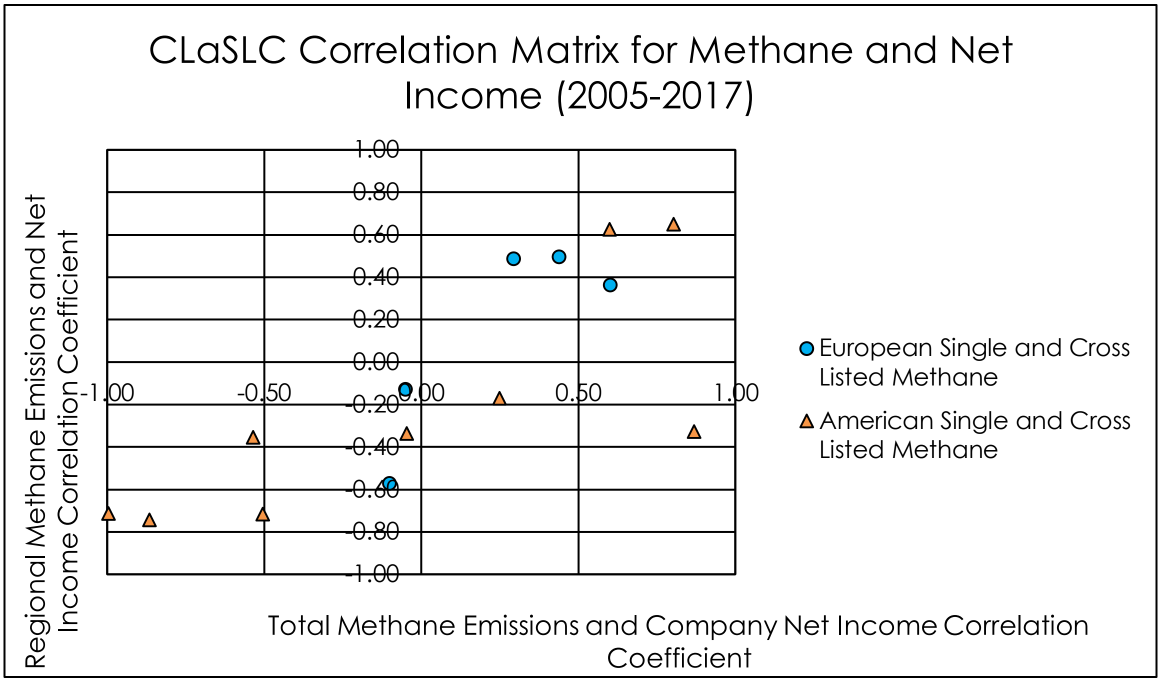

Figure 5.8: Correlation coefficients of total/regional methane emissions against total/regional net income for CLaSLCs. See Section 3.3.1 for description of the method behind this figure and Part 2 of the Bibliography for list of the raw data sources. Note that there is no clear difference in the correlations between methane emissions and economic performance for European CLaSLCs versus their U.S. counterparts though statistically there appears to be some difference.

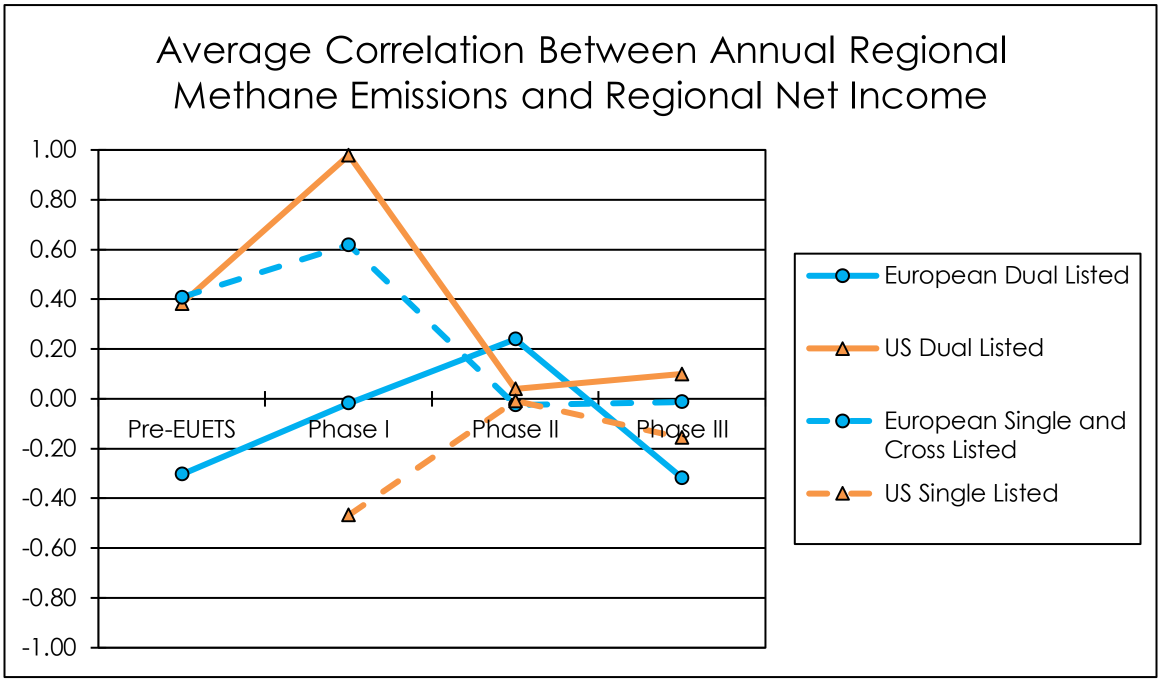

Figure 5.9: Average correlations between regional net income and regional methane emissions by phase of the EU ETS for European and U.S. CLaSLCs and the European and U.S. segments of DLCs. See Section 3.3.2 for description of the method behind this figure and Part 2 of the Bibliography for list of the raw data sources. Note that there is no discernable difference in the trends displayed in the European versus U.S. datasets during after Phase I of the EU ETS.

Section 5.2: Putting the Results in the Context of Previous Works

Section 5.2.1: The EU ETS' Encouragement of Emissions Reductions and Economic Growth

Section 1.2 briefly discussed the effectiveness of the EU ETS with particular emphasis placed upon the work of the OECD (2018) and the comparison between efforts of the U.S. and Germany to reduce carbon dioxide emissions. In general, there is a perception that the EU ETS has not been successful in achieving its goal of encouraging innovation and efficiency to reduce emissions while facilitating economic growth (Convery 2009; Skjaerseth, 2014; OECD, 2018) (see Sections 1.1 and 1.2). However, questions remain about whether there is still hope for the scheme to achieve its goals in the long run (de Perthuis, 2011, Koch et al., 2016).

As part of the Emissions Database for Global Atmospheric Research (EDGAR), Muntean et al. (2018) recorded carbon dioxide intensity (emissions per unit of Gross Domestic Product (GDP) in U.S. dollars) for every country across the world (see Figure 5.10).

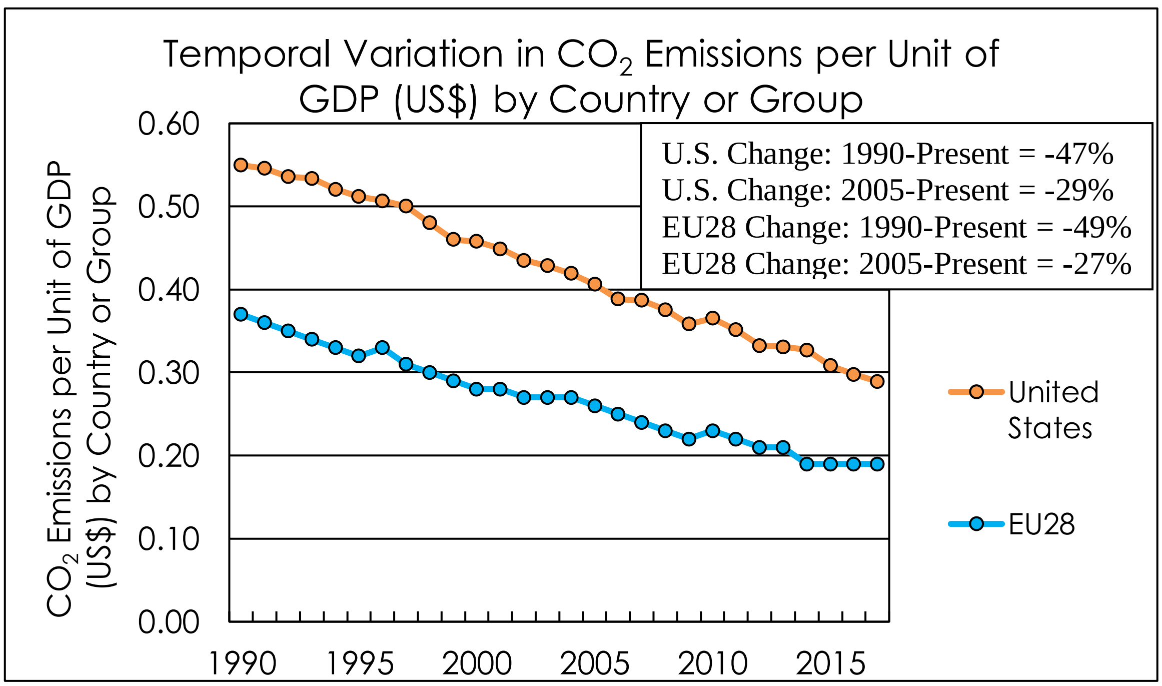

Figure 5.10: Temporal variation in carbon dioxide emissions per unit of GDP (US$) by Country or Group. Data adapted from Muntean et al. (2018). Note that after the introduction of the EU ETS the U.S. outpaces the EU in its reduction of emissions intensity by a small amount.

From Figure 5.10, it is apparent that, although the EU has lesser carbon dioxide emissions per unit of GDP, the U.S. is reducing its carbon dioxide intensity at a faster rate than the EU. Given that the intention of the EU ETS was to reduce emissions and encourage economic growth (Skjaerseth and Wettestad, 2009) it is therefore surprising that the EU does not outpace the U.S. in this particular aspect, though this could be the result of starting with a lower original emissions intensity. Analysis conducted on Muntean et al.'s (2018) data for the purposes of this study suggests that the EU's rate of reduction in carbon intensity decreased following the initiation of the EU ETS in 2005; though this was also true for the U.S. (see Table 5.1).

Country/Group	**Prior to the EU ETS**	**During the EU ETS**
United States	-0.010	-0.009
European Union	-0.007	-0.006

Table 5.1: Rate of change for the United States' and European Union's carbon dioxide emissions intensity before and during the EU ETS; 1990 to 2005 and 2005 to 2017 respectively. Rate of change calculated from the slope of the line of best fit for each curve. Data adapted from Muntean et al. (2018). Note the faster rate of change for the U.S. versus the EU during the EU ETS.

From the disparity in the rates of change recorded in Table 5.1 it is clear that there is a degree of uncertainty as to whether the EU ETS has thus far been successful in achieving its goal to reduce emissions and promote economic growth. The analysis conducted on the oil and gas sector during this study also infers such a conclusion, but that the occurrence of external factors likely exerts greater influence on the oil and gas sector than the scheme itself (see Section 5.3). It is apparent that oil and gas operators in Europe have performed worse economically than their U.S. counterparts and it is possible that allowance and penalty payments as a result of the EU ETS have contributed to this poorer performance, though this cannot be confirmed from the results in Section 4. It is also acknowledged that there are a number of external factors which may have also significantly influenced the results (see Section 5.3).

This conclusion also aligns with the data produced by Kortelainen (2018) and conclusions inferred from the work of the OECD (2018). Kortelainen (2018) noted a 17.5% decrease in total emissions for the 2005-2017 period across all sectors monitored by the EU ETS. However, this overall decrease was strongly influenced by considerable reductions in the power and heat and lime and cement production sectors. Emissions in the oil and gas sector were not reduced in the period between 2005 and 2017, despite a significant decrease in the total emissions allocated to the sector by the EU ETS (see Figure 2.1). The discrepancy between the rapid reductions in emissions allowances in Phase III of the EU ETS and the actions by operators to reduce their verified emissions (see Figure 2.1) is interpreted to be partly responsible for the poor economic performance of European operators relative to their U.S. counterparts. By comparing Figures 2.1 and 2.2 it is clear that there is a relationship between a reduction in the allowances made to the oil and gas sector (reflective of reductions made across all sectors of the EU ETS at this time) and a propensity for monitored sectors in general, including the oil and gas sector, to increasingly be in exceedance of their emissions allowances. Associated with this exceedance of emissions allowances are financial penalties imposed by the EU ETS. However, the OECD

(2018) also note a general decrease in carbon dioxide emissions intensity for the oil and gas sector between 2005 and 2017.

The imposition of such financial penalties, in the range of 100 euros per metric ton of emissions above the annual allowance (European Commission, 2019a), were intended to encourage the efficiencies, innovation and growth outlined under the initial proposition of the scheme (Skjaerseth and Wettestad, 2009). However, it appears from the results outlined by Convery (2009), de Perthuis (2011), Kortelainen (2018), Muntean et al. (2018) and the OECD (2018) that the intention of such penalties is not reflected in reality. One potential explanation is that operators in Europe have generally not made a significant attempt to reduce their annual emissions of monitored gases and therefore are in exceedance of reduced allowances for which in they are subject to financial penalties. Although an alternative is that there is simply a long lag time between their actions to reduce emissions and the results of these actions. This may have contributed to their poorer economic performance under the EU ETS relative to their U.S. counterparts. However, this cannot be concluded from the results produced by this study.

Section 5.2.2: The Use of Pricing versus Quantity Instruments

As a quantity mechanism, emissions trading schemes are expected to offer greater control over monitored variables where information is asymmetrically distributed or there is considerable information uncertainty (Menanteau, Finon and Lamy, 2003). This condition characterizes emissions monitoring in the EU. Therefore, a successful EU ETS should offer greater control over emissions than carbon taxation and good control over emissions quantities in general. However, it is apparent that this has not been the case but the reasons appear to be structural. For example, as discussed in Section 5.2.1, the penalties imposed have not been sufficiently severe so as to change operators' practices with regard to emissions in the oil and gas sector, which is broadly reflective of similar shortcomings across all sectors of the scheme (see Section 1.3).

When Weitzman (1974) first discussed quantity and pricing instruments for tying any given variable to economic performance he was not able to propose one method over the other in order to achieve optimal results. Weitzman (1974) suggested that quantity methods placed greater inherent value on control of the given variables while pricing methods were more economically efficient. Summers (2007) has since commented that extensive regulatory approaches are "more likely to be economically inefficient and regressive". It appears that cap-and-trade in the context of the EU ETS has been economically inefficient and given the results of this study it is also apparent that the scheme has been regressive for the European oil and gas sector: oil and gas operators in Europe have performed poorer than their U.S. counterparts as a partial consequence of the EU ETS (see Section 5.2.1). Given conclusions within the literature broadly produce similar conclusions it is not surprising that U.S. favor trends toward the introduction of emissions taxation over cap-and-trade if either were to be adopted in this country. Though criticisms leveled at the EU ETS include an economically, as opposed to environmentally, focused approach (Reyes and Gilbertson, 2010; Webster, 2017) it would perhaps be more efficient to employ pricing mechanisms (emissions taxation) over quantity mechanisms (cap-and-trade) in the future given the results produced by the EU ETS. Weitzman (1974) noted the strong early preference within the economic community for pricing mechanisms and it appears that the sentiment remains the same today. Given the complex and relatively recent implementation of widespread cap-and-trade schemes, there is at present, no conclusive evidence to strongly infer that pricing mechanisms are any more successful than quantity mechanisms (Milliman and Prince, 1989; Jung et al., 1996; Requate and Unold, 2003; Andrew, 2008; Andersen and Greaker, 2018).

SECTION 5.3: ADDITIONAL FACTORS OF INFLUENCE

Section 5.3.1: Unilateral Policies within EU Member States

As mentioned in Section 1.2, Phase III of the EU ETS (from 2013 to the present) saw a shift from individual national allowances per sector to a single allowance for each sector across the entirety of the scheme (European Commission, 2019a). However, as apparent from the work of Skeates and Innes (2018) in Figure 1.2 there are a number of EU member states, including Germany, which have implemented their own emissions floor prices and taxes in addition to a number of unilateral environmental policies. In some cases, these unilateral policies may provide a more appealing environment for oil and gas operators while the opposite may be true in others. Therefore, these unilateral policy variations between member states may partially account for the results produced in this study.

Skeates and Innes (2018) infer an equivalent cost of carbon on the EU ETS of $16 per ton across Phase III of the scheme. However it is evident in Figure 1.2 that a number of EU member states, including France, Norway and Sweden have unilateral policies with higher costs of carbon (in exceedance of $50 per ton). Given that the majority of the EU's oil and gas production occurs in the North Sea, greater than 90% from the United Kingdom, Norway and Denmark (EU Offshore Authorities Group, 2019), the implementation of unilateral carbon floor prices greater than the allowance cost on the EU ETS in this region has likely exerted influence on the results of this study..

Analysis of individual member states from the data provided by Muntean et al. (2018) supports the interpretation that there is unilateral variation within the EU, and by extension a variation in exposure to the EU ETS (see Table 5.2). This variation is most prominent in the large reduction of Spain's rate of change and Germany's stagnation, due potentially in part to Spain's ambitious carbon policy and the rapid uptake of appropriate renewable projects in the country (Neslen, 2018). From examples such as this it is apparent that the policies of individual member states, particularly those responsible for the majority of oil and gas production, exert differing influence on the practices of emitters. Therefore, it is suggested that unilateral variation in policies specific to each member state may have accounted for results produced in this study which are not accounted for in the method utilized.

Country	**Prior to the EU ETS**	**During the EU ETS**
France	-0.004	-0.004
Germany	-0.008	-0.004
Spain	0.000	-0.007
United Kingdom	-0.010	-0.009
European Union	-0.007	-0.006

Table 5.2: Rate of change for the European Union' and influential members states' carbon dioxide emissions intensity before and during the EU ETS; 1990 to 2005 and 2005 to 2017 respectively. Rate of change calculated from the slope of the line of best fit for each curve. Data adapted from Muntean et al. (2018). Note the wide variation in the rates of change of individual members of the EU.

Section 5.3.2: Variation in Trends in Emissions and Costs per Barrel Produced

It is also important to consider that not all oils (and gases) are produced under identical conditions. Each have greenhouse gas emissions and cost profiles associated with the blend and are distributed geographically as a function of the geology of the producing basin. In this way, some blends are simply more prone to higher emissions as a function of the processes involved in their production (Carnegie Endowment for International Peace, 2019).

Gordon et al.'s (2015) index of thirty global oil blends identifies significant variation in the upstream, midstream and downstream processes associated with the production of petroleum products from each barrel. Gordon et al. (2015) highlight the nature of the chemistry of the oil and the production environment as the key drivers of variation in the emissions produced associated with the upstream processes for each of the oils considered. Gordon et al. (2015) and Di Lullo et al. (2016) identify factors associated with the composition of the blend and location and depth of the reservoir as key drivers of both upstream and downstream emissions. Associated with the former is the gas content, the state of degradation and the water content of the oil while the latter two relate to the depth of the reservoir and the location of the well in an extreme environment (Gordon et al., 2015; Di Lullo et la., 2016). It is possible that these factors have influenced both the regional emissions and regional economic performance of the companies assessed as part of this study.

According to the Carnegie Endowment for International Peace (2019), blends produced in Europe and the U.S. have average upstream emissions profiles of 28 and 58 kilograms of carbon dioxide equivalent respectively per barrel produced (see Figure 5.11). This indicates that typically each barrel of oil produced under the purview of the EU ETS will have inherently lesser emissions associated with its production than the U.S. equivalent. It is therefore likely that the results of this study are subject to this influence. Given that European barrels have inherently lesser emissions associated with their production, it is inferred that this factor manifests as a more positive skew for European operators relative to their U.S. counterparts. Each barrel produced in Europe results in less emissions than the U.S. equivalent and therefore a lesser penalty under the EU ETS than would be applied if there were parity between the emissions profiles. As a consequence of the lesser emissions per European barrel produced it is therefore likely that if emissions per barrel were normalized across the two regions (Europe and the U.S.) European operators would perform poorer economically, emitting more carbon dioxide and therefore subject to greater penalties under the EU ETS. There would therefore be a more pronounced difference in the results produced for European versus U.S. operators.

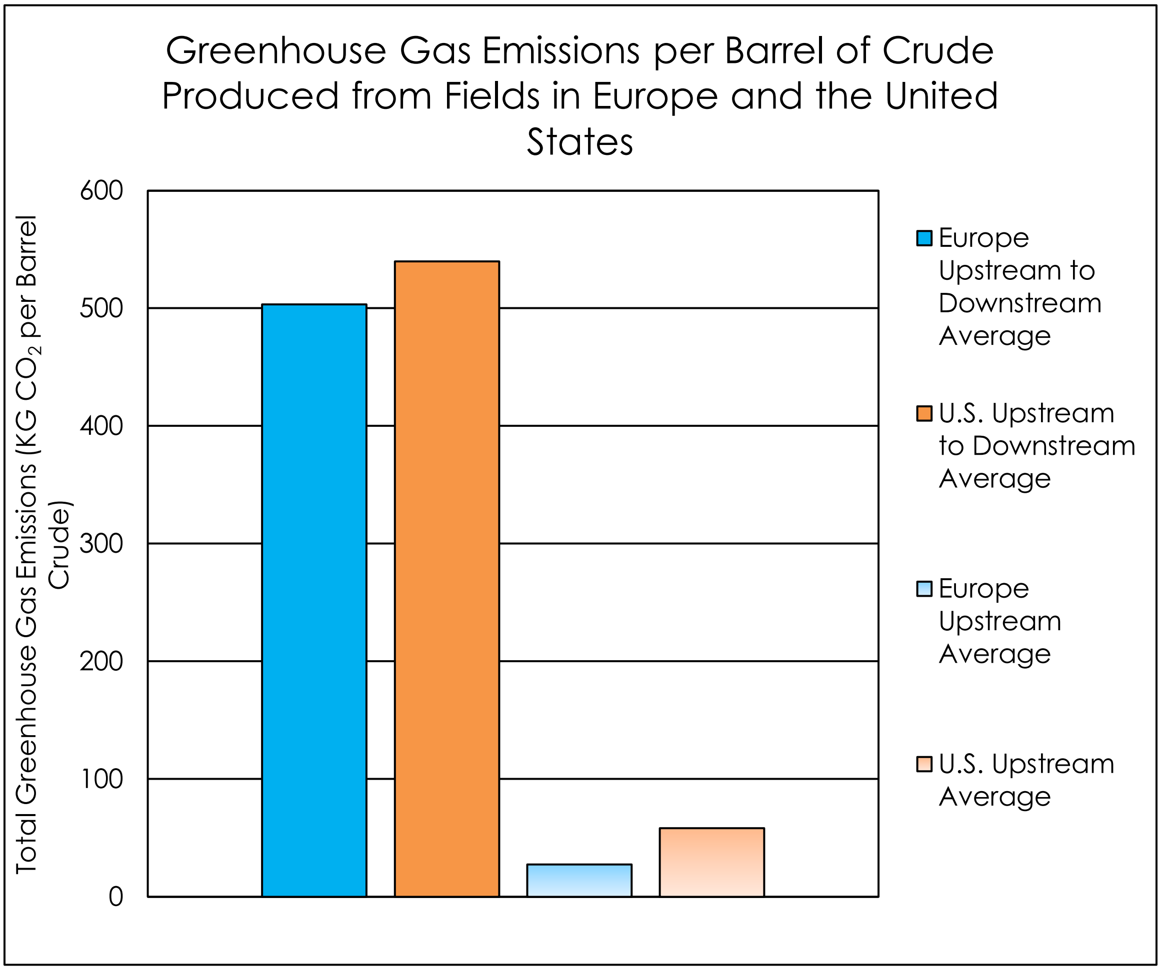

Figure 5.11: Average emissions generated per barrel produced in Europe and the U.S. Data adapted from Gordon et al. (2015) and the Carnegie Endowment for International Peace (2019). Note lower emissions per barrel in Europe versus the U.S.

Consequently, the works of Gordon et al. (2015) and the Carnegie Endowment for International Peace (2019) confirm that factors not considered within the scope of this study have likely influenced its results. However, given that typical emissions per barrel are less for European operators there is likely a positive skew to European economic performance and therefore should operators be normalized to the same emissions per barrel the results of this study may more conclusively infer that the EU ETS has exerted a negative impact on European operators relative to their U.S. counterparts. However, it must be noted that the averages calculated from the Gordon et al's (2015) and the Carnegie Endowment for International Peace's (2019) data are skewed by the presence of California blends requiring steam flooding which creates high emissions profiles. By removing these blends, the U.S. upstream average decreases to 48 kilograms of carbon dioxide equivalent per barrel produced but this change is not sufficient to make upstream emissions intensity in the U.S. less than Europe.

Furthermore, the cost associated with each barrel produced must be considered for each region, as the cost to produce per region has an impact on the economic performance of operators within different regions. A significantly higher cost to produce in Europe would result in poorer economic performance relative to the U.S., regardless of any involvement of the EU ETS. An example of such a difference in production costs would be the U.S. shale boom which helped to reduce emissions and allowed high volume cheap production. This event is independent and exogenous to the EU ETS and therefore exerted influence on the results noted. According to Rystad Energy (2016), the average upstream cost of the major producing fields in Europe (North Sea) is approximately $30 compared to $20 for the major fields in the U.S. (see Figure 5.12).

Given the difference of roughly $10 per barrel between the producing regions the results of this thesis are, at least partially, influenced by differences in production costs between Europe and the U.S. The more expensive production costs associated with European operations are reflected in decreased net income per barrel than in the U.S. which negatively impacts economic performance for European operators relative to their U.S. counterparts. It is therefore likely that poorer economic performance in Europe is partly a consequence of trends in production costs and not as a direct consequence of penalties and payments resulting from the EU ETS. This study did not take into account the influence of geographic variations in emissions and cost trends weakening the overall conclusions which potentially contributed to the inconclusive results generated (see Chapter 4).

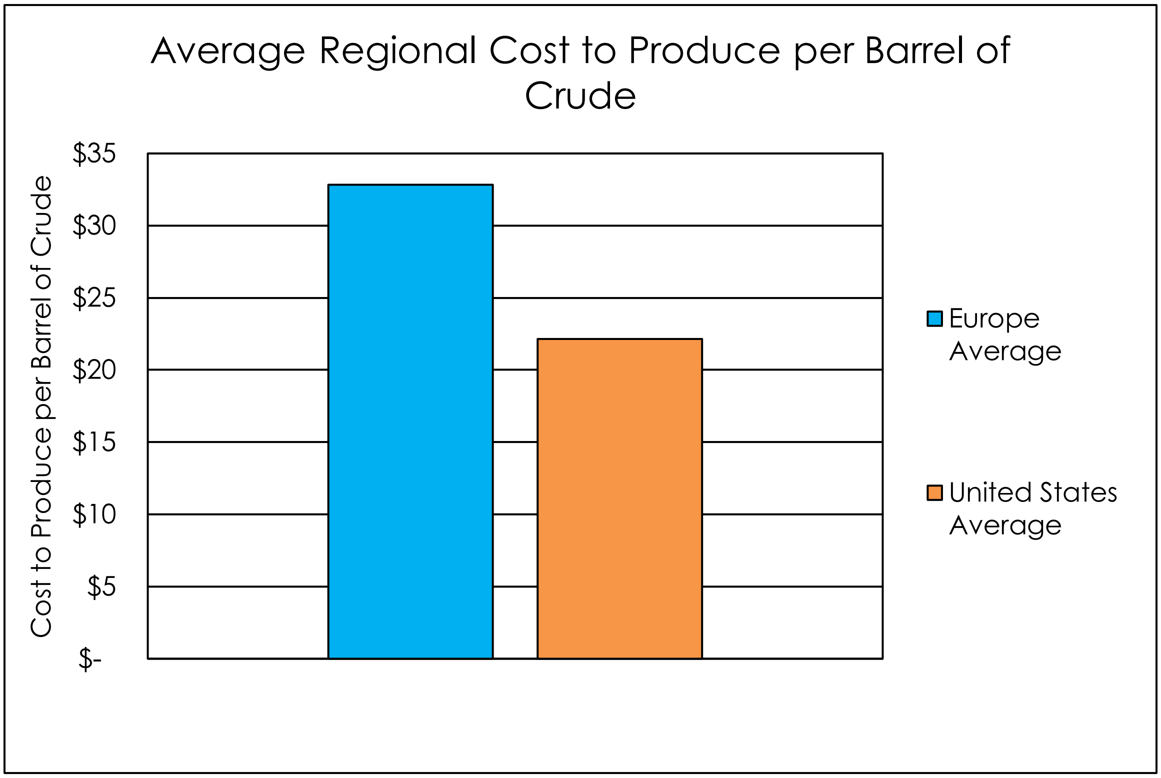

Figure 5.12: Average cost to produce from major fields in Europe and the United States. Data adapted from Rystad Energy (2016). Note a lower cost to produce in the U.S.

Section 5.3.3: Macroeconomic Events: The 2008 Financial Crisis

The occurrence of significant macroeconomic events during the 2005 through 2017 period has also likely exerted considerable influence on the results of this study. Figure 3.3 showed median ROE across the LSE and NYSE on the whole and across the sample datasets analyzed as part of this study. From this figure (Figure 3.3) it is evident that the 2008 financial crisis adversely affected the economic performance of operators across both exchanges, though the NYSE appears to have been impacted more significantly.

The 2008 financial crisis originated as a sub-prime mortgage crisis through 2007 and finally becoming a global recession in December 2007 (Holt, 2009). Holt (2009) and Allen and Carletti (2010) point to generally low interest rates and overly positive market sentiment as the drivers of this financial crisis, factors which also affected the oil and gas sector at this time. Given that the origins of the financial crisis lie in the U.S. housing market (Holt, 2009; Allen and Carletti, 2010) it is not surprising that the NYSE was more significantly impacted than the LSE. However the ramifications of a significant reduction in the availability of U.S. capital were certainly felt by European operators (see Figure 3.3). Intuitively, the drying up of the international capital markets likely exerted a negative impact on the economic performance of oil and gas operators both in Europe and the U.S. However, the knock-on effects of low interest rates in the early 2000’s, and their associated increase through 2005-2009 also had a detrimental impact on operations. According to Boyte-White (2018), low interest rates reduce the cost of debt to fund companies and projects and their Weighted Average Cost of Capital (WACC).

By lowering WACC, the company's discount rate is also generally lowered (unless a hurdle rate is used). Through this lowering of the discount rate, it is more common for companies to pursue riskier projects (those that are closer to breakeven) (Boyte-White, 2018). In the years preceding the financial crisis (2000-2005), low interest rates likely encouraged the uptake of riskier projects by oil and gas operators and therefore exacerbated the impact of the 2008 financial crisis on the economic performance of the operators analyzed in this study. Though it is challenging to quantify the precise impact of the 2008 financial crisis on European versus U.S. operators, it is apparent that such a significant macroeconomic event exerted a strong negative influence on the economic performance of operators across the world and therefore likely influenced the results of this study.

Section 5.3.4: Commodity Price Fluctuations

A regional difference in commodity prices between Europe and the U.S. over the analysis period also likely exerted influence on the results of the study. Generally, the LSE sample dataset showed less correlation between the price of Brent crude than did the NYSE sample with the price of WTI crude (inferring that variations in commodity price may disproportionately affect the U.S. compared with the European oil and gas sector) (see Figures 5.13 and 5.14), while both exchanges showed a relatively similar correlation between ROE (economic performance) and Henry Hub prices (see Figure 5.15).

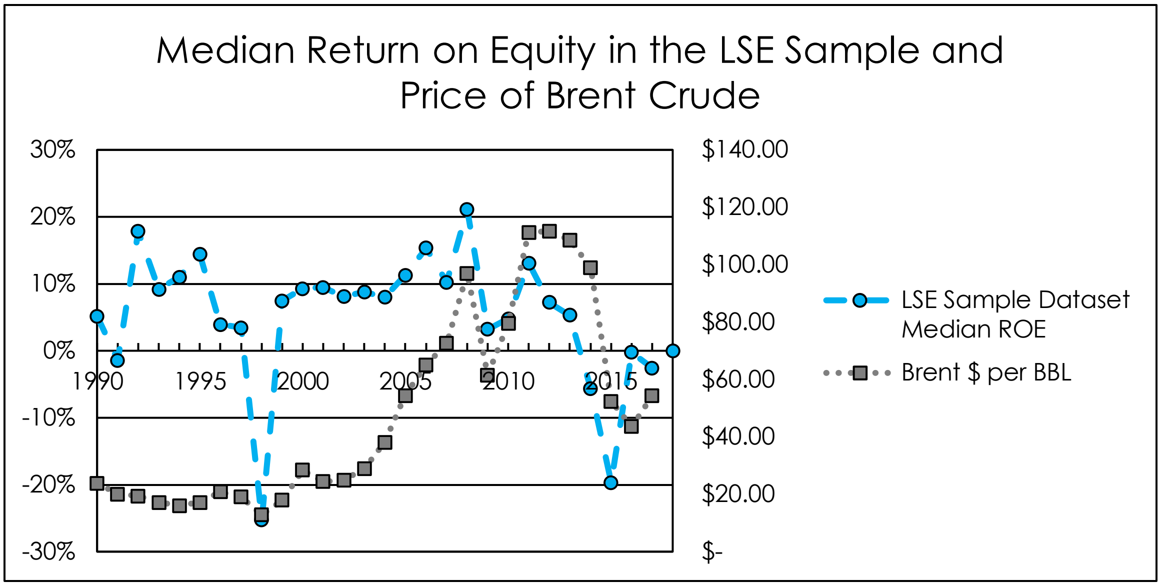

Figure 5.13: Median return on equity in the LSE sample and the price of Brent crude. Data adapted from Macrotrends (2018). Note a relatively strong correlation between ROE and oil price, excluding 2000 through 2008.

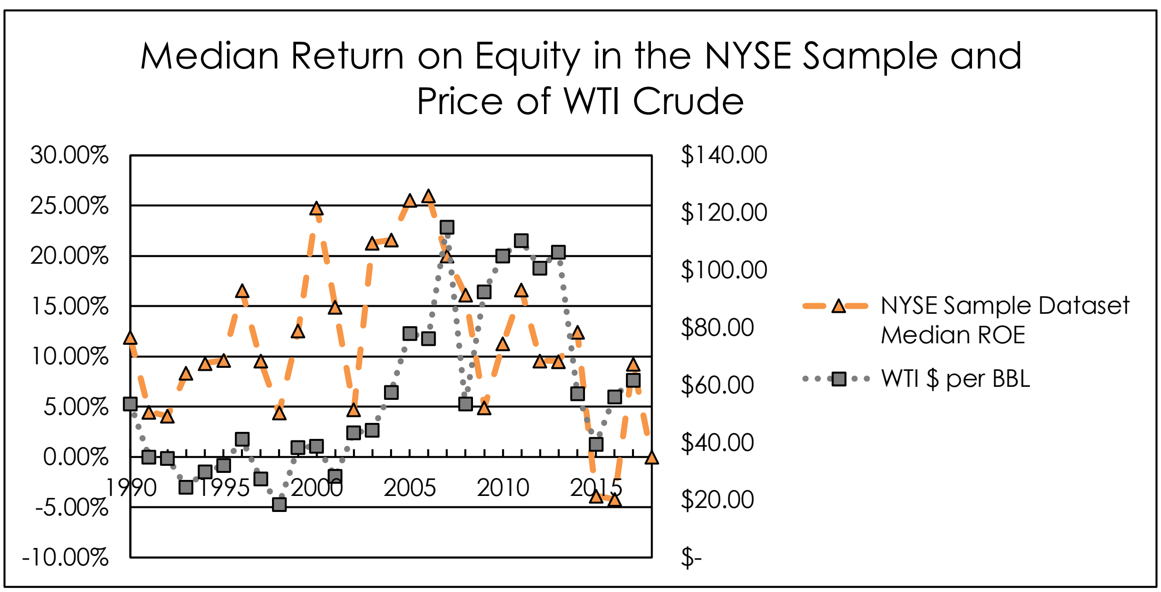

Figure 5.14: Median return on equity in the NYSE sample and the price of WTI crude. Data adapted from Macrotrends (2018). Note a somewhat stronger correlation between ROE and oil price for the NYSE than the LSE sample.

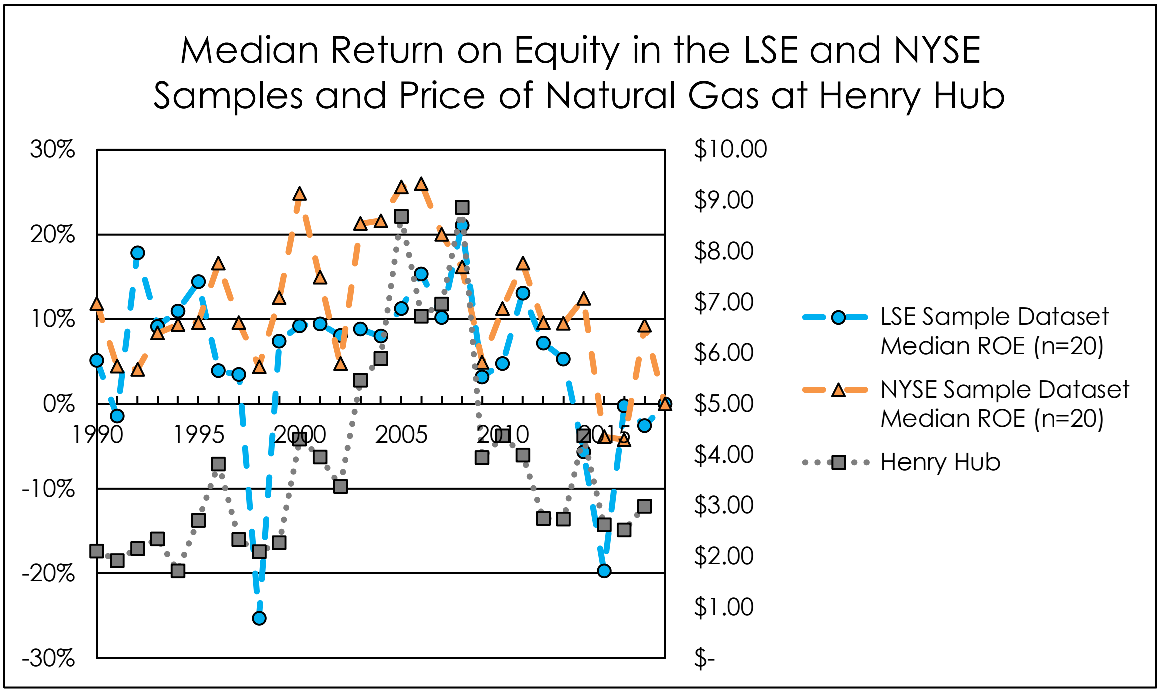

Figure 5.15: Median return on equity in the LSE and NYSE sample and the price at Henry Hub. Data adapted from Macrotrends (2018).

It is reasonable to assume that fluctuations in commodity price, especially the differential between Brent and WTI, have exerted at least a degree of influence on the economic performance of operators, most notably so during the 2014 oil price crash. Under the assumptions proposed by Weiner (1991) and expanded upon by Liu (2018), the oil market globalization assumption states that prices of crude oils of the same quality should be strongly correlated. With this assumption under consideration, Figures 5.13 and 5.14 show similar trends in the prices of Brent and WTI, though the exact prices rarely align. Additionally, the occurrence of the oil price crash in 2014 (during Phase III of the EU ETS) likely exerted considerable negative impact on the economic performance of all companies, in addition to resulting in decreased production (and therefore decreased emissions).

Though it is challenging to quantify the impact of such a drastic crash, many economists cite the U.S. shale boom, resulting in increased supply, as a key driver of the crash (Samuelson, 2014). Consequently, it may be reasonable to infer that European operators were disproportionately negatively affected by this crash than their U.S. counterparts. If this is the case, then the 2014 price crash has likely exerted considerable influence on the overall and incremental correlations generated as part of this study. It is therefore important to acknowledge the role of commodity price fluctuations in the context of this study given that it is difficult to directly account for such fluctuations in the method. Lower production costs in the U.S. (see Figure 5.12)) and a potentially disproportionate exposure to the 2014 oil price crash between regions may have exacerbated the negative economic performance relative to emissions for European operators compared with their U.S. counterparts.

SECTION 5.4: LIMITATIONS

Section 5.4.1: General Limitations of the Thesis

Though the method utilized in this study has been subject to refinement over the course of the analysis there remain many limitations and concerns with regards to the conclusions as discussed in the immediately preceding sections. In using market capitalization during initial sample selection the intention was to minimize the impact of company size on the results of the study. However, the total median market capitalization of companies in the oil and gas sector listed on the NYSE and LSE differ by a multiple of four, approximately $5B on the LSE compared with approximately $20B on the NYSE. This difference is in part reflective of a significantly younger average IPO age within the

LSE sample dataset (2004) compared with that of the NYSE dataset (1990) in addition to factors related to the state of development for each of these capital markets. The initial selection of 3 DLCs and 40 CLaSLCs across both the LSE and NYSE was intended to represent a statistically robust sample. However, due to a lack of emissions data the total number of companies studied comprehensively was closer to 20 than 40 as originally intended (though all 3 DLCs and 40 CLaSLCs had their economic performance recorded). This decrease in the size of the sampled datasets brings into question the reliability of the conclusions. There are also limitations associated with the regionalization of emissions and net income. In the case of emissions, this information was only available for companies on the whole and therefore the regional approximation was utilized (as described in Section 3.2). Using a regional approximation which accounts for regional variations in production and refining was interpreted to be the best method in approximating regional emissions. However, a lack of data concerning regionalized refining throughput for integrated operators such as Hess and Andeavor limited the application of this method. Furthermore, the regional revenue approximation utilized for companies which did not publish net income by geographic segment fails to account for regional fiscal variations which are pertinent to analysis conducted under this study. Though the majority of companies sampled did not require this approximation, use of this approximation weakens the validity of the results for the 4 companies for which it was utilized. Furthermore, an inability to quantify the factors described in Section 5.3 also weakens the results of this study. In acknowledging and discussing the additional factors and limitations associated with this study and its method the intention is to ensure that this work is as transparent as possible.

Section 5.4.2: General Limitations of Event Studies

The method outlined in this study roughly follows that of an event study as initially outlined in the landmark papers by Ball and Brown (1968) and Fama et al. (1969). As such, it suffers from many of the limitations shared by numerous studies published since the method was initially suggested. Event studies typically focus on the impact of a specific event on the value of a firm, be it a macroeconomic event, regulatory change or company announcement (MacKinlay, 1997). In this case, the regulatory event was the introduction of the EU ETS.

However, the method employed to study a continuous regulatory event, such as the EU ETS, introduces more uncertainty than when applied to a single event. MacKinlay (1997) noted the importance of event-date uncertainty as a limiting factor in the robustness of event studies. In conventional event studies, event-date uncertainty typically arises from an uncertainty pertaining to whether the market was informed prior to the recorded event-date. For instance, if there was an information leak prior to an official announcement and the announcement date was taken as the event-date, then the disparity results in event-date uncertainty. With regards to this study, event-date does not refer to an uncertainty in the start date of the event (the beginning of 2005) but to the fact that given the continuous occurrence, and regulatory evolution, of the EU ETS it is challenging to define conclusive short term estimation windows associated with the event-date. For conventional event studies, event-date uncertainty allows for the interference of other factors not accounted for by the identified event-date. In this case, the EU ETS has run for over twelve years and is currently ongoing. Therefore, the comparable datasets analyzed throughout this study may be subject to influences not accounted for in the methodology of this study, discussed previously in Section 5.3.

SECTION 5.6: FURTHER WORK

From the work conducted under the scope of this study it is clear that further consideration is required both with regards to evaluating the efficacy of cap-and-trade schemes and the evaluation of oil and gas companies through an environmental, social and governance (ESG) lens. Both of these additional areas of study would significantly benefit from a standardized rubric for disclosing emissions data within the global oil and gas sector. At present, oil and gas companies operating under emissions trading schemes are required by law to record annualized emissions data for all three emissions types assessed within this study. However, these companies are not presently required to publish the recorded emissions in their 10-K statements or annual reports. Given the rapidly growing popularity of social and environmentally conscious investment funds and practices and the public nature of companies listed on any stock exchange, it should now fall within the fiduciary responsibility of oil and gas operators to allow common investors access to historic and current emissions data. Through the publication of such datasets it is suggested that the industry will be capable of achieving further transparency which in turn will be beneficial from both a public relations and financial performance standpoint. Such benefits may include the ability to evaluate operators on an historical emissions efficiency basis (see Figure 5.16) or in the ability to quantify investors' ESG preferences (i.e. the premia expected from investments made under an ESG portfolio relative to performance in environmental and social factors) through an establishment of ESG premiums for expected returns on equity. Additionally, wider publication of emissions data will allow for the development of more robust datasets than those constructed for the purposes of this study. In improving the robustness of the datasets used to analyze the efficacy of cap-and-trade policy and carbon taxation it is suggested that in the future it may be possible to empirically conclude what factors have a more tangible effect on greenhouse gas emissions. As the uptake of carbon taxation and cap-and-trade schemes is gaining more traction globally, the introduction of further, robustly populated, datasets will contribute to a more robust argument, in favor of either quantity or pricing mechanisms with regards to carbon policy.

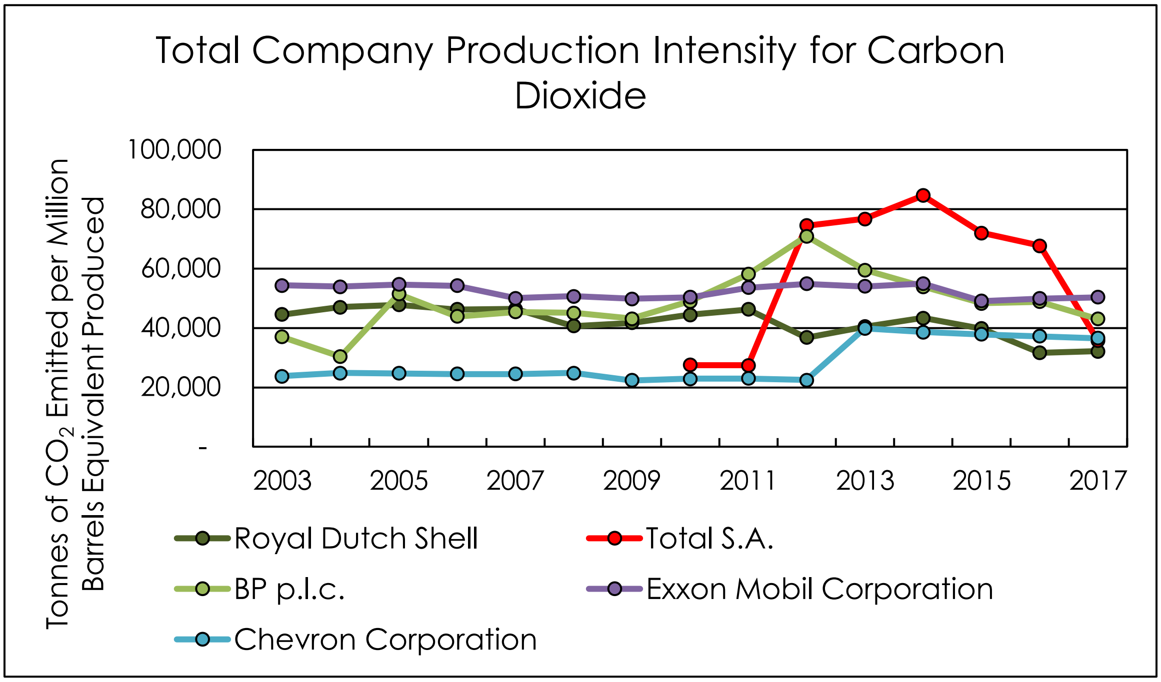

Figure 5.16: Production intensity with regards to carbon dioxide emissions for the three DLCs and two largest CLaSLCs. Note that over the course of the analysis production intensity has not significantly decreased for any of the five companies.

SECTION 5.7: CONCLUSIONS

This study has attempted to address the impact of the EU ETS on the oil and gas sector in Europe. In doing so, it has addressed the broad hypothesis that oil and gas companies under the EU ETS would have a more negative overall, and increasingly negative through time, correlation between economic performance and emissions monitored by the scheme. This has been addressed through an adapted event study methodology, concluding that the EU ETS may have potentially impacted European operators negatively with regards to economic performance in comparison with their U.S.

counterparts while acknowledging many other factors not studied were likely greater contributors.

Results from this study proved statistically inconclusive as to whether the EU ETS has exerted influence on the negative economic performance of European oil and gas companies relative to their U.S. counterparts. Therefore, it is plausible that the scheme may have played a part, through its imposition of allowances and penalties, in negatively impacting the economic performance of oil and gas companies operating within it. However, this cannot be concluded from the results of this study.

Appendices

APPENDIX A: LINKS TO RAW DATA

Please click here to access and download the dataset built and analyzed during this study, available on Open Science Framework. Alternatively, access the supplemental materials provided with this document on the University of Texas Online Library.

Appendix B: Overall and Incremental Correlations Additional Results

Appendix B.1: Overall Correlation between Economic Performance and Emissions

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=18)	0.67	0.24	0.46	-0.29
Total (n=8)	0.17	0.42	-0.88	0.10
BP (n=18)	0.46	0.32	0.21	0.62

Table B.1: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs. ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe and U.S. Net Income analyzed against regional annual carbon dioxide emissions.

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=15)	0.67	0.29	-0.12
Chevron (n=16)	-0.23	-0.10	-0.58
ConocoPhillips (n=14)	-0.13	.05	-0.52
Occidental* (n=3)	0.99	0.99	0.99
Canadian Natural Resources (n=13)	-0.54	-0.32	0.20
Marathon Petroleum (n=11)	0.10	0.36	0.36
Anadarko Petroleum (n=3)	-0.23	-0.15	-0.09
Andeavor (n=8)	0.15	0.13	0.13
Hess (n=12)	0.40	0.26	-0.60
Devon Energy* (n=3)	-0.96	-0.99	-0.56
Marathon Oil (n=8)	-0.19	-0.20	-0.54
Apache (n=6)	0.21	0.32	0.17

Table B.2: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs. ROE and Total Net Income analyzed against total annual carbon dioxide emissions. U.S. Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=18)	-0.23	0.31	0.13
John Wood Group (Wood) (n=5)	0.79	0.78	0.73
Tullow Oil (n=10)	-0.20	-0.08	0.24
Cairn Energy (n=18)	0.61	0.54	-0.41
Premier Oil (n=14)	-0.44	-0.31	-0.33
Faroe Petroleum* (n=2)	-1.00	-1.00	-1.00
Enquest (n=5)	-0.10	-0.11	-0.16

Table B.3: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs. ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=18)	0.56	0.37	0.54	0.33
Total (n=8)	0.69	0.59	0.33	0.26
BP (n=13)	0.69	0.59	0.45	0.75

Table B.4: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs. ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe and U.S. Net Income analyzed against regional annual nitrous oxide emissions.

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=16)	0.55	0.20	0.03
Chevron (n=16)	-0.66	-0.09	-0.31
ConocoPhillips (n=15)	0.52	0.50	0.43
Occidental* (n=3)	0.95	0.96	1.00
Canadian Natural Resources (n=13)	-0.41	-0.37	-0.06
Pioneer Natural Resources* (n=2)	1.00	1.00	1.00
Andeavor (n=9)	-0.73	-0.80	-0.80
Hess (n=11)	-0.50	-0.35	-0.75
Marathon Oil (n=11)	-0.59	-0.68	-0.69
Apache (n=5)	0.12	0.19	0.17

Table B.5: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs. ROE and Total Net Income analyzed against total annual nitrous oxide emissions. U.S. Net Income analyzed against regional annual nitrous oxide emissions. Perfect and near perfect correlations due to limited data availability (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=18)	-0.60	0.31	0.09
Tullow Oil (n=6)	0.20	0.00	0.12
Cairn Energy (n=18)	0.61	0.13	-0.56
Premier Oil (n=8)	0.30	0.35	0.19

Table B.6: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs. ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe Net Income analyzed against regional annual nitrous oxide emissions.

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=18)	0.44	0.01	-0.57	-0.72
Total (n=8)	0.55	0.43	0.57	-0.05
BP (n=18)	0.50	0.43	0.27	-0.57

Table B.7: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for DLCs. ROE and Total Net Income analyzed against total annual methane emissions. Europe and U.S. Net Income analyzed against regional annual methane emissions.

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=11)	-0.74	-0.54	-0.36
Chevron (n=15)	0.11	0.25	-0.17
ConocoPhillips (n=14)	-0.06	-0.05	-0.34
Occidental (n=3)	0.55	0.60	0.63
Pioneer (n=3)	-0.91	-0.87	-0.75
Hess (n=13)	-0.62	-0.50	-0.72
Devon Energy* (n=3)	-1.00	-1.00	-0.71
Marathon Oil (n=6)	0.82	0.87	-0.33
Apache (n=5)	0.90	0.80	0.65

Table B.8: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs. ROE and Total Net Income analyzed against total annual methane emissions. U.S. Net Income analyzed against regional annual methane emissions. Perfect and near perfect correlations due to limited data availability (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=18)	0.23	0.60	0.36
Tullow Oil (n=10)	0.22	0.29	0.49
Cairn Energy (n=18)	0.25	-0.10	-0.57
Premier Oil (n=8)	-0.10	-0.05	-0.13
Enquest (n=5)	0.35	0.44	0.49

Table B.9: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs. ROE and Total Net Income analyzed against total annual methane emissions. Europe Net Income analyzed against regional annual methane emissions.

Appendix B.2: Incremental Correlation between Economic Performance and Emissions

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=5)	0.73	0.98	0.09	0.47
BP* (n=5)	0.13	0.44	-1.00	0.65

Table B.10: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs prior to the EU ETS (2000-2004). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe and U.S. Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	**ROE**	**Total Net Income**	**U.S. Net Income**
ExxonMobil* (n=2)	1.00	-1.00	-1.00
Chevron (n=3)	-0.95	-0.05	-0.89

Table B.11: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs prior to the EU ETS (2000-2004). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. U.S. Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	**ROE**	**Total Net Income**	**Europe Net Income**
PJSC Lukoil (n=5)	N/A	-0.56	-0.79
Cairn Energy (n=5)	-0.51	-0.46	0.92
Premier Oil* (n=2)	-1.00	1.00	-1.00

Table B.12: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Change in Total and Regional Net Income) for European CLaSLCs prior to the EU ETS (2000-2004). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell* (n=3)	0.49	-0.72	-0.98	0.94
BP (n=3)	0.66	-0.77	0.32	0.43

Table B.13: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs during Phase I of the EU ETS (2005-2007). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe and U.S. Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=3)	0.56	-0.22	0.28
Chevron* (n=3)	-0.25	0.72	0.99
ConocoPhillips (n=3)	-0.78	0.07	-0.41
Canadian Natural Resources* (n=3)	0.90	0.99	0.31
Hess* (n=2)	-1.00	-1.00	-1.00

Table B.14: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs during Phase I of the EU ETS (2005-2007). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. U.S. Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=3)	N/A	0.89	0.57
Cairn Energy (n=3)	0.24	0.28	-0.10
Premier Oil* (n=3)	0.99	0.83	0.06

Table B.15: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs during Phase I of the EU ETS (2005-2007). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=5)	0.76	0.86	0.54	-0.77
Total* (n=3)	0.84	-0.89	0.94	-0.57
BP (n=5)	-0.43	-0.20	-0.47	0.39

Table B.16: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs during Phase II of the EU ETS (2008-2012). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe and U.S. Net Income analyzed against regional annual carbon dioxide emissions.

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=5)	0.46	0.49	-0.06
Chevron (n=5)	0.43	-0.03	0.15
ConocoPhillips (n=5)	0.90	0.91	-0.15
Canadian Natural Resources (n=5)	-0.83	-0.80	0.59
Marathon Petroleum (n=5)	-0.40	-0.38	-0.38
Andeavor (n=3)	-0.29	-0.48	-0.48
Hess (n=5)	0.85	0.75	-0.16
Marathon Oil* (n=3)	-0.82	-0.96	0.49

Table B.17: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs during Phase II of the EU ETS (2008-2012). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. U.S. Net Income analyzed against regional annual carbon dioxide emissions.

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=5)	0.32	0.40	0.42
Tullow Oil (n=5)	0.33	0.79	0.40
Cairn Energy* (n=5)	0.79	0.59	1.00
Premier Oil* (n=5)	-0.25	0.99	-0.63

Table B.18: Correlation coefficients between annual rate of change in carbon dioxide emissions and economic performance (ROE and Annual Rates of Change in Total and Regional Net Income) for European CLaSLCs during Phase II of the EU ETS (2008-2012). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=5)	0.88	0.85	0.58	-0.42
Total (n=5)	-0.18	0.35	-0.42	0.26
BP (n=5)	0.91	0.78	0.76	0.63

Table B.19: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs during Phase III of the EU ETS (2013-2017). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe and U.S. Net Income analyzed against regional annual carbon dioxide emissions.

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=5)	0.19	0.16	0.15
Chevron (n=5)	0.70	0.69	-0.60
ConocoPhillips (n=5)	0.09	0.12	-0.48
Occidental* (n=3)	0.99	0.99	0.99
Canadian Natural Resources (n=5)	-0.26	-0.27	0.10
Marathon Petroleum (n=5)	-0.33	-0.04	-0.04
Anadarko Petroleum* (n=3)	-0.23	-0.15	-0.09
Andeavor (n=5)	-0.42	-0.72	-0.72
Hess (n=5)	0.60	0.46	-0.33
Devon Energy* (n=3)	-0.96	-0.99	-0.56
Marathon Oil (n=5)	0.08	0.12	-0.71
Apache (n=5)	-0.28	-0.06	-0.36

Table B.20: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs during Phase III of the EU ETS (2013-2017). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. U.S. Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=5)	0.33	0.67	0.53
John Wood Group (Wood) (n=5)	0.79	0.78	0.73
Tullow Oil (n=5)	0.23	0.21	-0.38
Cairn Energy (n=5)	0.34	0.35	0.35
Premier Oil (n=5)	0.43	0.56	0.22
Faroe Petroleum* (n=2)	-1.00	-1.00	-1.00
Enquest (n=5)	0.00	-0.02	-0.05

Table B.21: Correlation coefficients between carbon dioxide emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs during Phase III of the EU ETS (2013-2017). ROE and Total Net Income analyzed against total annual carbon dioxide emissions. Europe Net Income analyzed against regional annual carbon dioxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=5)	-0.84	0.05	0.72	-0.53
BP* (n=5)	0.82	-1.00	-1.00	-0.54

Table B.22: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs prior to the EU ETS (2000-2004). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe and U.S. Net Income analyzed against regional annual nitrous oxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=5)	N/A	-0.51	-0.30
Cairn Energy (n=5)	0.04	0.08	0.61

Table B.23: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs prior to the EU ETS (2000-2004). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe Net Income analyzed against regional annual nitrous oxide emissions.

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=3)	0.28	-0.20	-0.55	-0.93
BP* (n=3)	0.34	0.40	-0.95	0.33

Table B.24: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs during Phase I of the EU ETS (2005-2007). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe and U.S. Net Income analyzed against regional annual nitrous oxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil* (n=3)	-0.69	-1.00	0.97
Chevron* (n=3)	-0.50	0.88	0.96
ConocoPhillips (n=3)	-0.01	0.81	0.04
Canadian Natural Resources* (n=3)	0.14	0.45	0.94

Table B.25: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs during Phase I of the EU ETS (2005-2007). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. U.S. Net Income analyzed against regional annual nitrous oxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil* (n=3)	N/A	1.00	0.94
Cairn Energy (n=3)	0.89	0.91	N/A

Table B.26: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs during Phase I of the EU ETS (2005-2007). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe Net Income analyzed against regional annual nitrous oxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=5)	-0.38	-0.36	0.12	-0.13
Total* (n=3)	0.12	-0.92	0.58	0.08

Table B.27: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs during Phase II of the EU ETS (2008-2012). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe and U.S. Net Income analyzed against regional annual nitrous oxide emissions.

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=5)	0.70	0.72	0.34
Chevron (n=5)	0.46	0.77	0.67
ConocoPhillips (n=5)	0.82	0.81	0.09
Canadian Natural Resources (n=5)	0.36	0.24	-0.15
Andeavor (n=4)	-0.84	-0.81	-0.81
Hess (n=5)	-0.10	-0.48	-0.80
Marathon Oil* (n=3)	-0.80	-0.96	0.80

Table B.28: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs during Phase II of the EU ETS (2008-2012). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. U.S. Net Income analyzed against regional annual nitrous oxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=5)	-0.19	0.53	0.46
Cairn Energy* (n=5)	-0.11	-0.33	1.00
Premier Oil (n=3)	0.94	0.84	-0.77

Table B.29: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs during Phase II of the EU ETS (2008-2012). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe Net Income analyzed against regional annual nitrous oxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=5)	0.00	0.00	-0.07	-0.72
Total (n=5)	-0.03	0.33	-0.68	0.38
BP (n=5)	0.64	0.19	0.52	0.67

Table B.30: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for DLCs during Phase III of the EU ETS (2013-2017). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe and U.S. Net Income analyzed against regional annual nitrous oxide emissions.

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=5)	0.69	0.68	0.28
Chevron (n=5)	-0.38	-0.40	-0.16
ConocoPhillips (n=5)	0.59	0.58	0.44
Occidental* (n=3)	0.95	0.96	1.00
Canadian Natural Resources (n=5)	-0.40	-0.36	-0.45
Pioneer Natural Resources (n=2)*	1.00	1.00	1.00
Andeavor (n=5)	-0.47	-0.79	-0.79
Hess (n=5)	-0.57	-0.51	-0.91
Marathon Oil* (n=5)	-0.47	-0.58	-0.98
Apache (n=5)	0.12	0.19	0.17

Table B.31: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs during Phase III of the EU ETS (2013-2017). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. U.S. Net Income analyzed against regional annual nitrous oxide emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=5)	0.25	0.80	-0.66
Tullow Oil (n=5)	0.24	-0.61	-0.21
Cairn Energy (n=5)	-0.52	-0.81	-0.68
Premier Oil (n=5)	-0.02	-0.10	0.14

Table B.32: Correlation coefficients between nitrous oxide emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs during Phase III of the EU ETS (2013-2017). ROE and Total Net Income analyzed against total annual nitrous oxide emissions. Europe Net Income analyzed against regional annual nitrous oxide emissions.

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=5)	0.42	0.04	0.36	0.76
BP* (n=5)	-0.98	-0.99	-0.37	0.00

Table B.33: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for DLCs prior to the EU ETS (2000-2004). ROE and Total Net Income analyzed against total annual methane emissions. Europe and U.S. Net Income analyzed against regional annual methane emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=5)	N/A	-0.47	-0.06
Cairn Energy (n=5)	0.94	0.88	0.88

Table B.34: Correlation coefficients between methane emissions and economic performance for European CLaSLCs prior to the EU ETS (2000-2004). ROE and Total Net Income analyzed against total annual methane emissions. Europe Net Income analyzed against regional annual methane emissions.

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell* (n=3)	0.83	-0.95	-0.97	0.98
BP* (n=3)	0.91	0.39	0.93	0.98

Table B.35: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for DLCs during Phase I of the EU ETS (2005-2007). ROE and Total Net Income analyzed against total annual methane emissions. Europe and U.S. Net Income analyzed against regional annual methane emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	U.S. Net Income
Chevron* (n=3)	0.93	-0.98	-0.19
ConocoPhillips (n=3)	-0.75	0.11	-0.63
Hess (n=3)	0.48	-0.34	-0.58

Table B.36: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs during Phase I of the EU ETS (2005-2007). ROE and Total Net Income analyzed against total annual methane emissions. U.S. Net Income analyzed against regional annual methane emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil* (n=3)	N/A	0.99	0.62
Cairn Energy (n=3)	0.90	0.88	N/A

Table B.37: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs during Phase I of the EU ETS (2005-2007). ROE and Total Net Income analyzed against total annual methane emissions. Europe Net Income analyzed against regional annual methane emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=5)	0.07	0.04	0.27	-0.52
Total (n=3)	-0.70	-0.28	0.79	0.93
BP (n=5)	-0.08	0.33	-0.34	-0.30

Table B.38: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for DLCs during Phase II of the EU ETS (2008-2012). ROE and Total Net Income analyzed against total annual methane emissions. Europe and U.S. Net Income analyzed against regional annual methane emissions.

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=5)	0.08	0.44	-0.25
Chevron (n=5)	0.21	0.76	0.55
ConocoPhillips (n=5)	0.90	0.91	-0.15
Hess (n=5)	-0.53	0.55	-0.18

Table B.39: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs during Phase II of the EU ETS (2008-2012). ROE and Total Net Income analyzed against total annual methane emissions. U.S. Net Income analyzed against regional annual methane emissions.

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=5)	0.23	-0.77	-0.51
Tullow Oil (n=5)	0.31	0.58	0.36
Cairn Energy* (n=5)	-0.19	-0.30	1.00
Premier Oil* (n=3)	1.00	0.96	-0.95

Table B.40: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs during Phase II of the EU ETS (2008-2012). ROE and Total Net Income analyzed against total annual methane emissions. Europe Net Income analyzed against regional annual methane emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income	U.S. Net Income
Shell (n=5)	-0.85	-0.70	-0.91	-0.65
Total (n=5)	-0.92	-0.68	-0.90	0.36
BP (n=5)	0.06	-0.20	0.85	0.58

Table B.41: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for DLCs during Phase III of the EU ETS (2013-2017). ROE and Total Net Income analyzed against total annual methane emissions. Europe and U.S. Net Income analyzed against regional annual methane emissions.

Company	ROE	Total Net Income	U.S. Net Income
ExxonMobil (n=5)	-0.21	-0.22	0.13
Chevron (n=5)	0.35	0.34	-0.57
ConocoPhillips (n=5)	0.49	0.50	0.19
Occidental (n=3)	0.55	0.60	0.63
Anadarko (n=3)	-0.91	-0.87	-0.75
Hess (n=5)	-0.29	-0.38	-0.55
Devon Energy* (n=3)	-1.00	-1.00	-0.71
Marathon Oil (n=5)	0.85	0.90	-0.42
Apache (n=5)	0.90	0.80	0.65

Table B.42: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for U.S. CLaSLCs during Phase III of the EU ETS (2013-2017). ROE and Total Net Income analyzed against total annual methane emissions. U.S. Net Income analyzed against regional annual methane emissions. Perfect and near perfect correlations due to limited data availability and short analysis window (see asterisked companies).

Company	ROE	Total Net Income	Europe Net Income
PJSC Lukoil (n=5)	-0.04	0.51	-0.70
Tullow Oil (n=5)	0.49	0.50	0.17
Cairn Energy (n=5)	-0.44	-0.53	-0.53
Premier Oil (n=5)	0.40	0.44	0.51
Enquest (n=5)	0.35	0.44	0.49

Table B.43: Correlation coefficients between methane emissions and economic performance (ROE and Total and Regional Net Income) for European CLaSLCs during Phase III of the EU ETS (2013-2017). ROE and Total Net Income analyzed against total annual methane emissions. Europe Net Income analyzed against regional annual methane emissions.

Appendix B.3: Plots of Overall Correlation between Economic Performance and Emissions

(Appendix starts on following page)

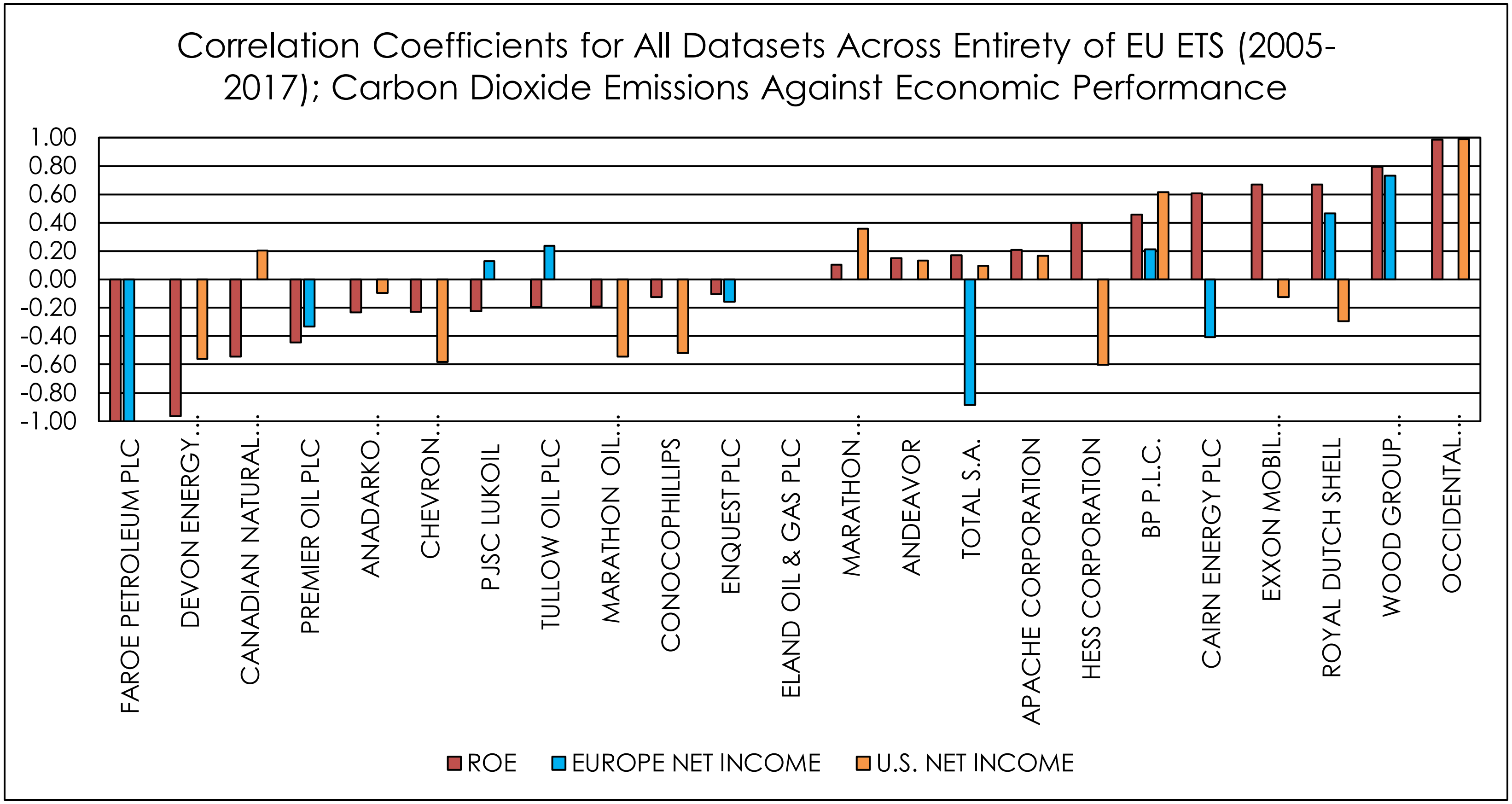

Figure B.1: Correlation coefficients for carbon dioxide emissions against economic performance (ROE and Regional Net Income) for all datasets over the period 2005 through 2017. See Appendix A for raw data and Appendix B for tables of correlation coefficients.

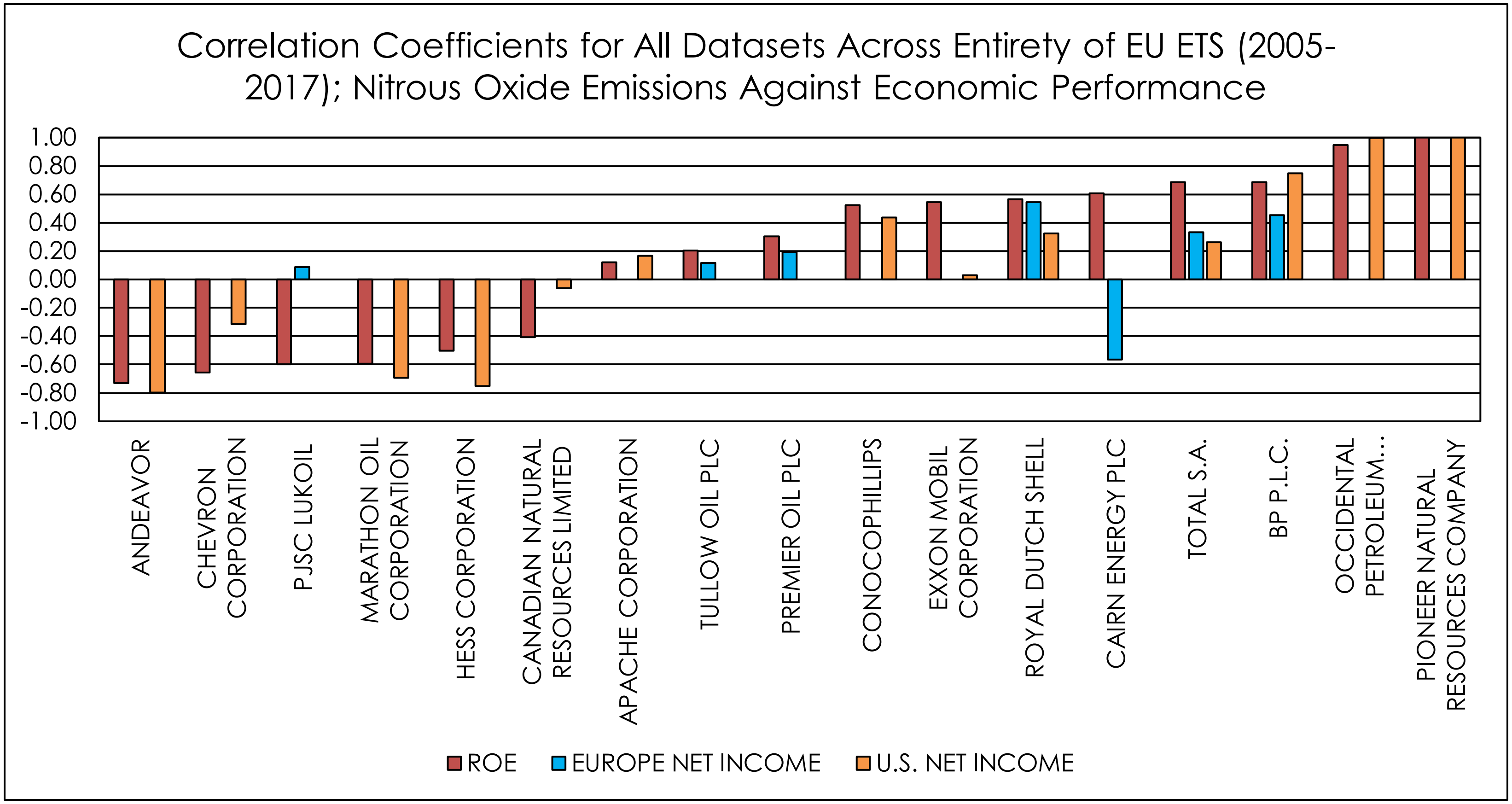

Figure B.2: Correlation coefficients for nitrous oxide emissions against economic performance (ROE and Regional Net Income) for the period 2005 through 2017. See Appendix A for raw data and Appendix B for tables of correlation coefficients.

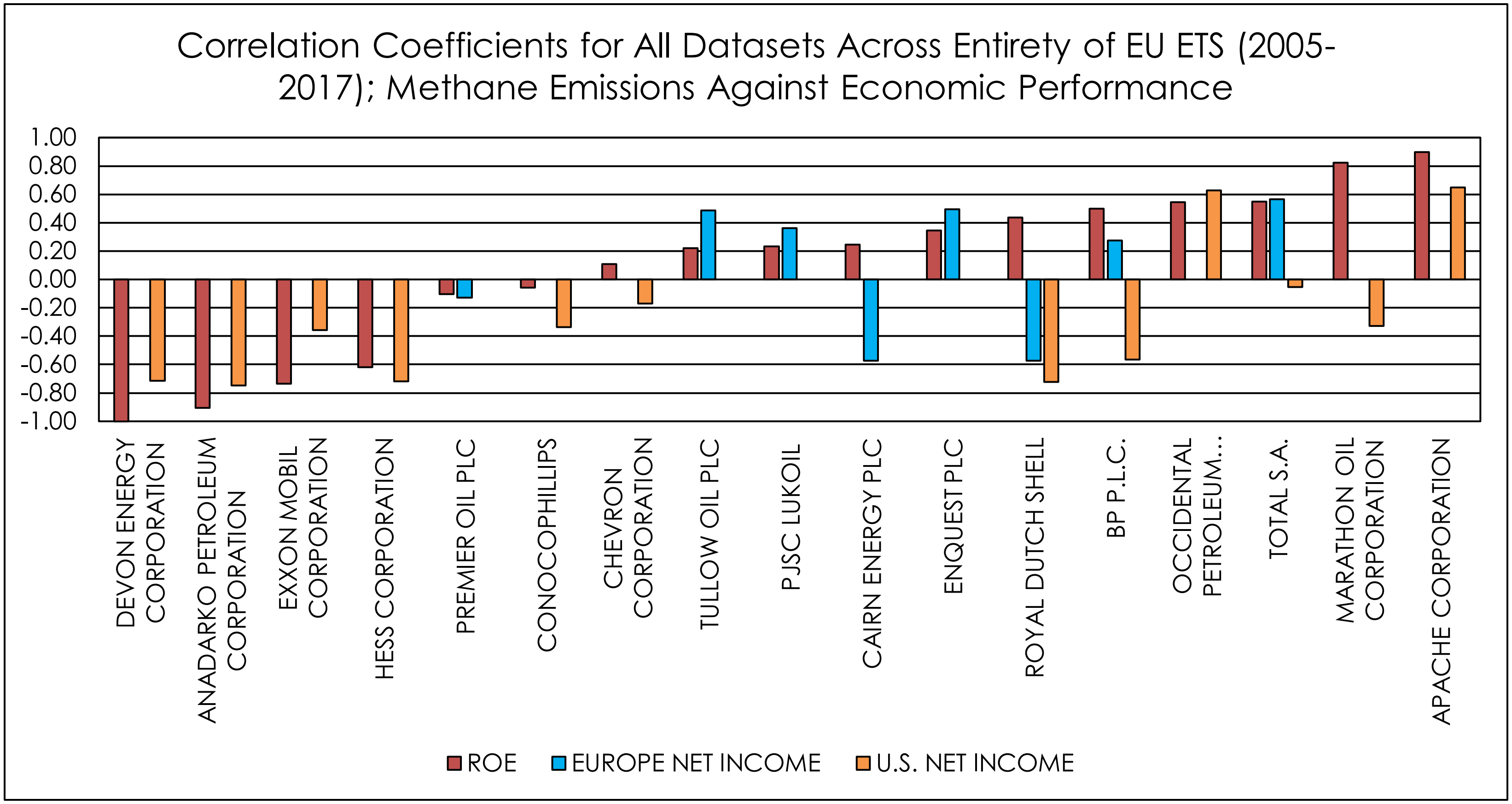

Figure B.3: Correlation coefficients for methane emissions against economic performance (ROE and Regional Net Income) for the period 2005 through 2017. See Appendix A for raw data and Appendix B for tables of correlation coefficients.

APPENDIX C: PLOTS OF RAW EMISSIONS DATA

(Appendix starts on following page)

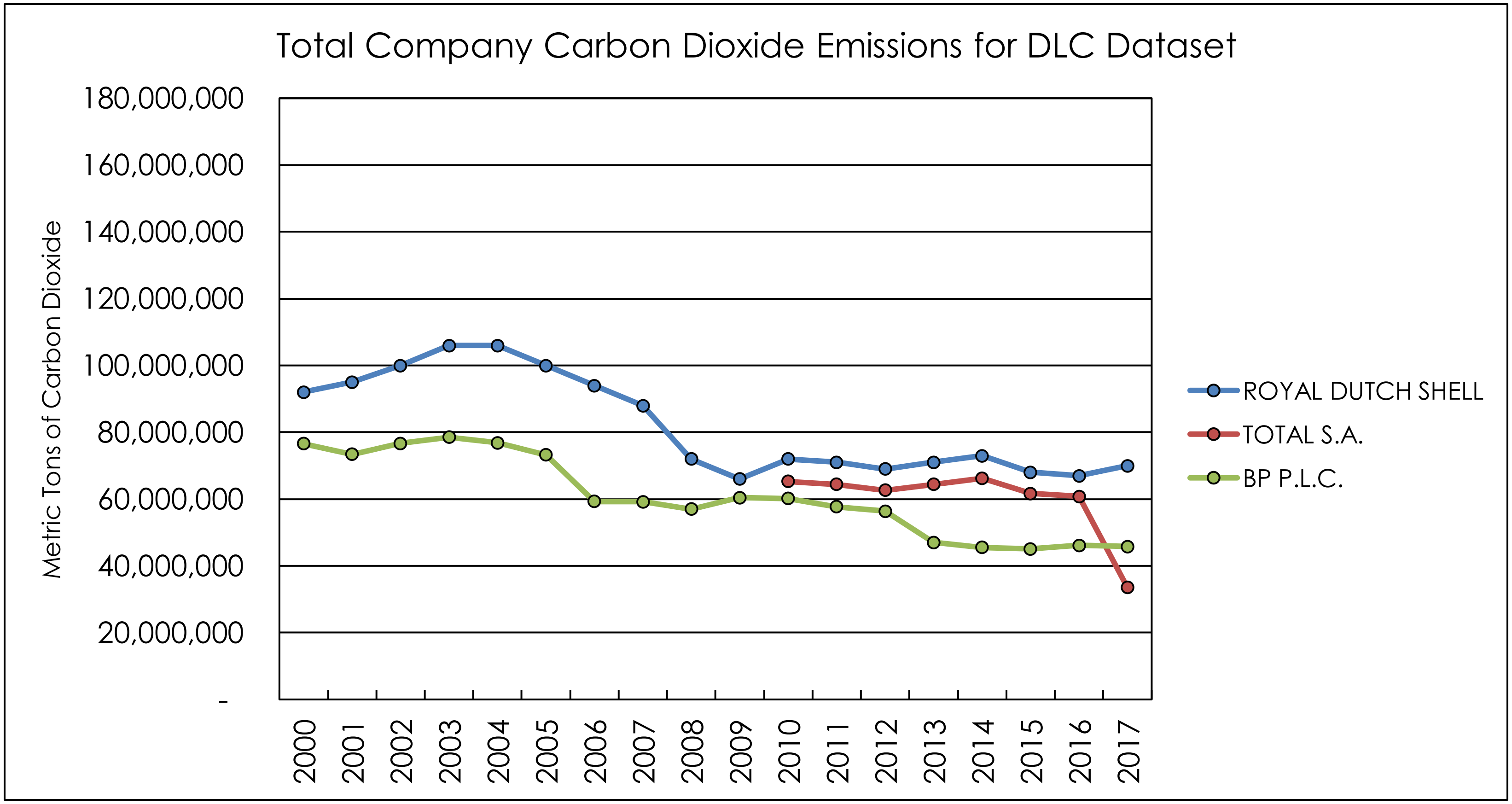

Figure C.1: Total company carbon dioxide emissions for DLCs. Plotted from the data available in Appendix A.

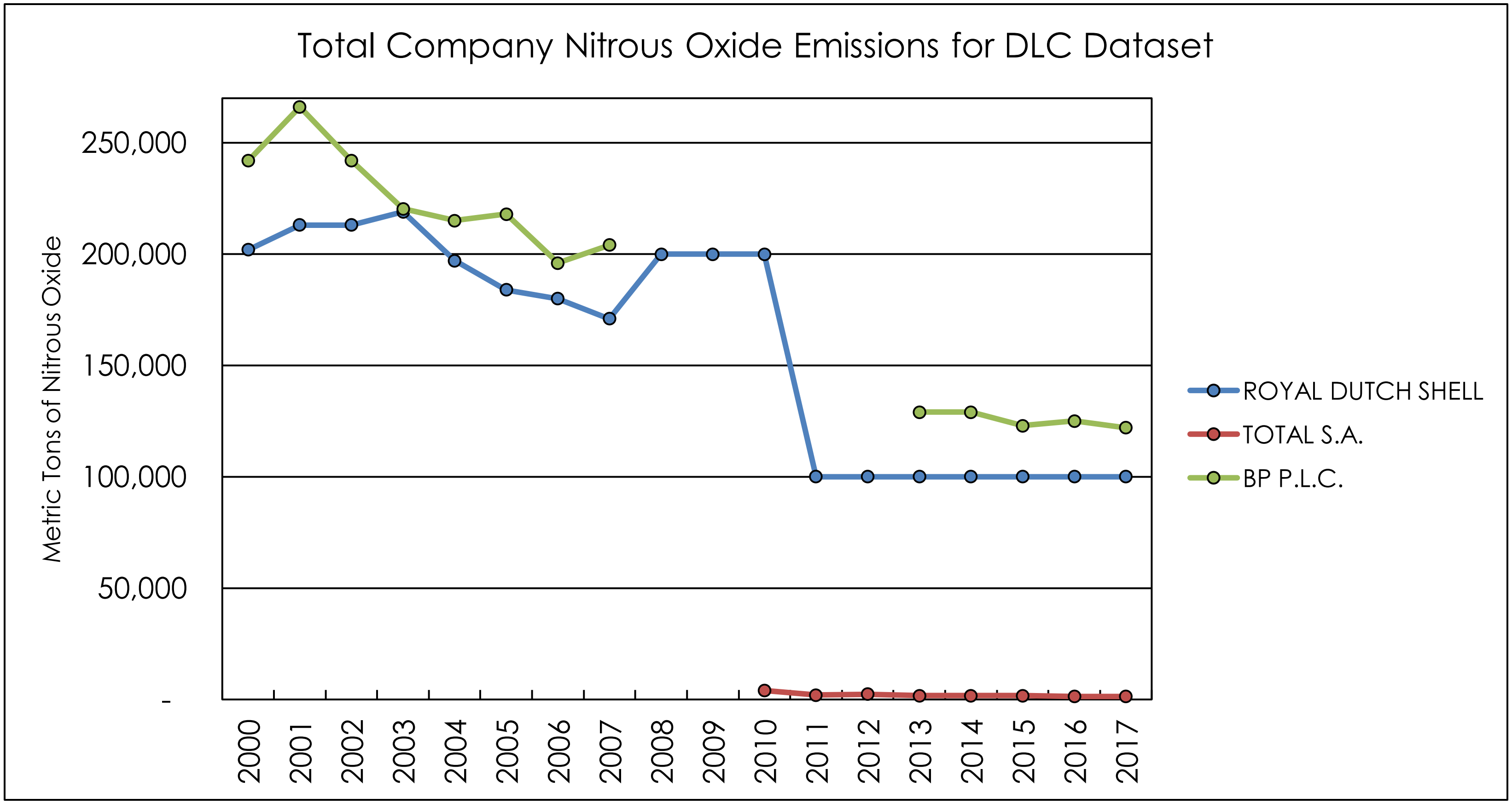

Figure C.2: Total company nitrous oxide emissions for DLCs. Plotted from the data available in Appendix A. Low emissions for Total inferred to be results of a reporting error.

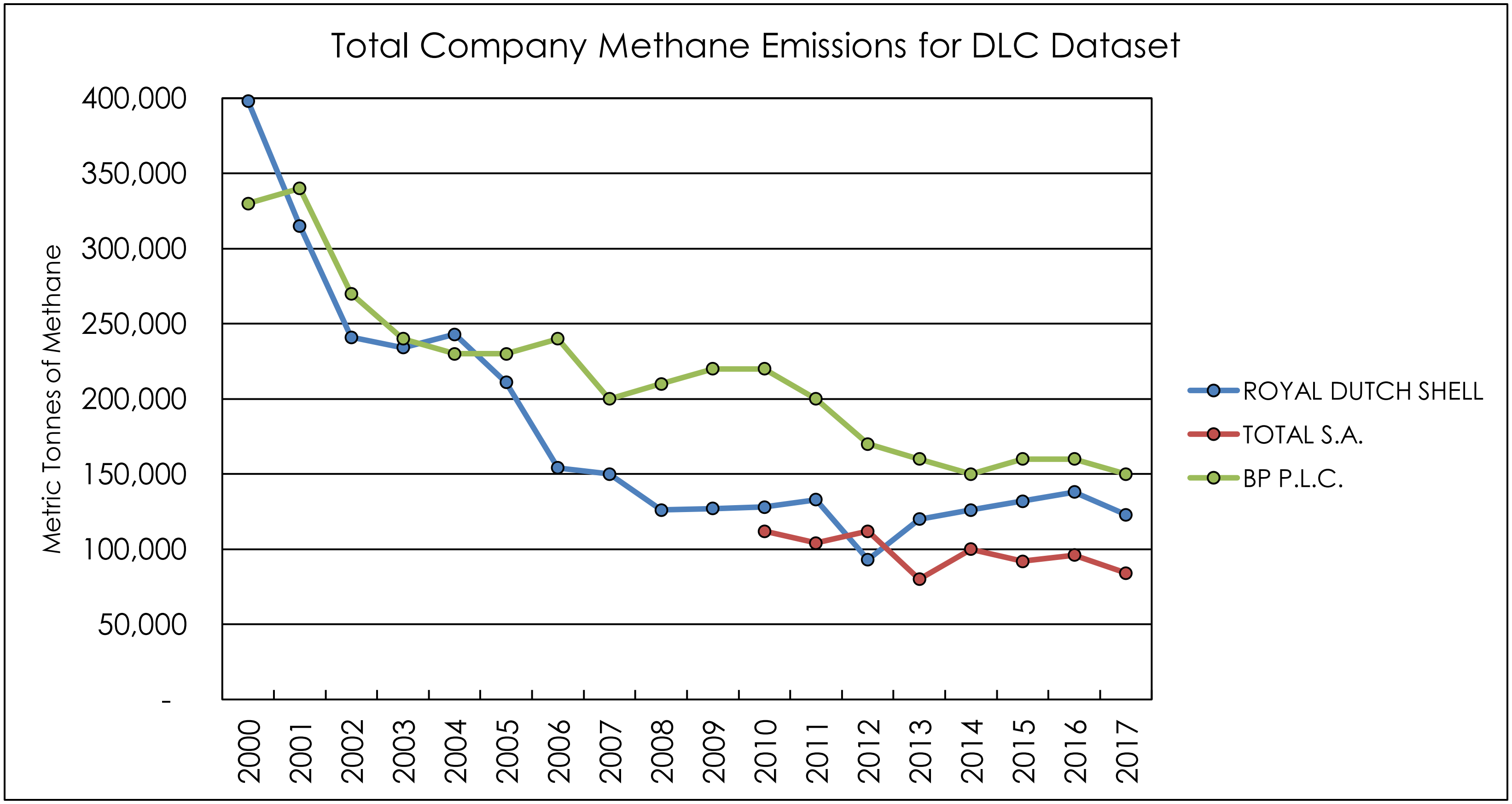

Figure C.3: Total company methane emissions for DLCs. Plotted from the data available in Appendix A.

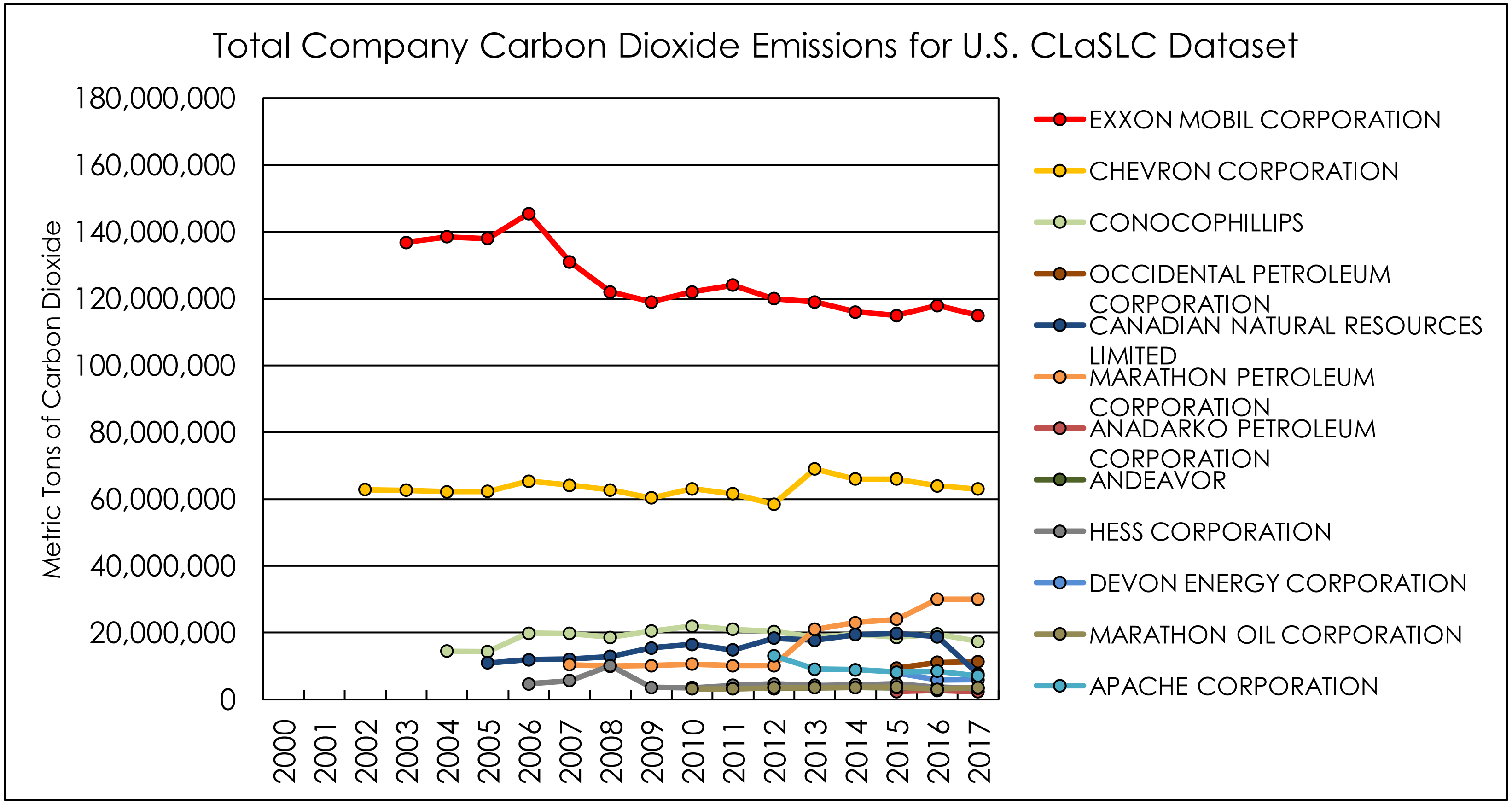

Figure C.4: Total company carbon dioxide emissions for U.S. CLaSLCs. Plotted from the data available in Appendix A.

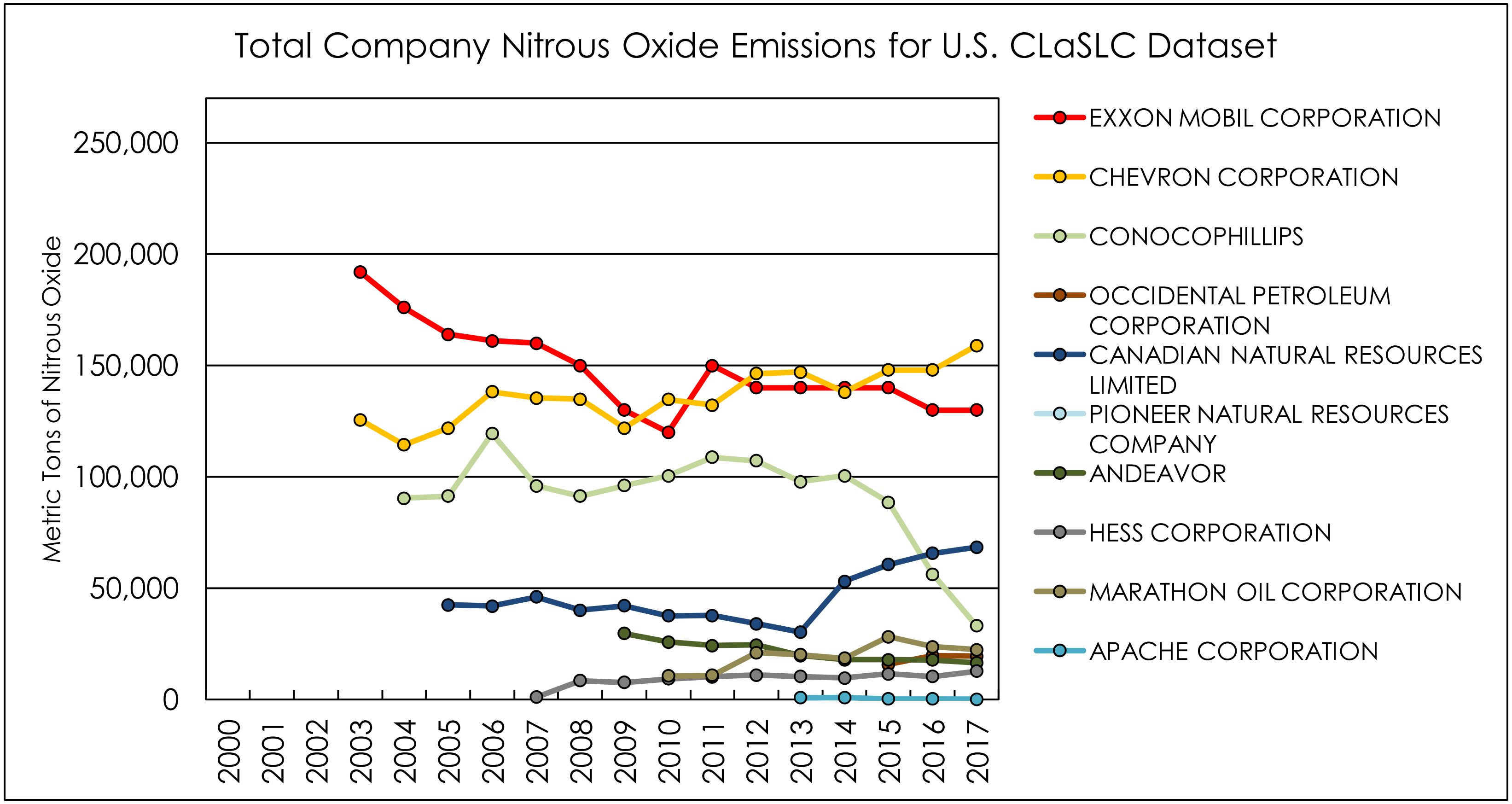

Figure C.5: Total company nitrous oxide emissions for U.S. CLaSLCs. Plotted from the data available in Appendix A.

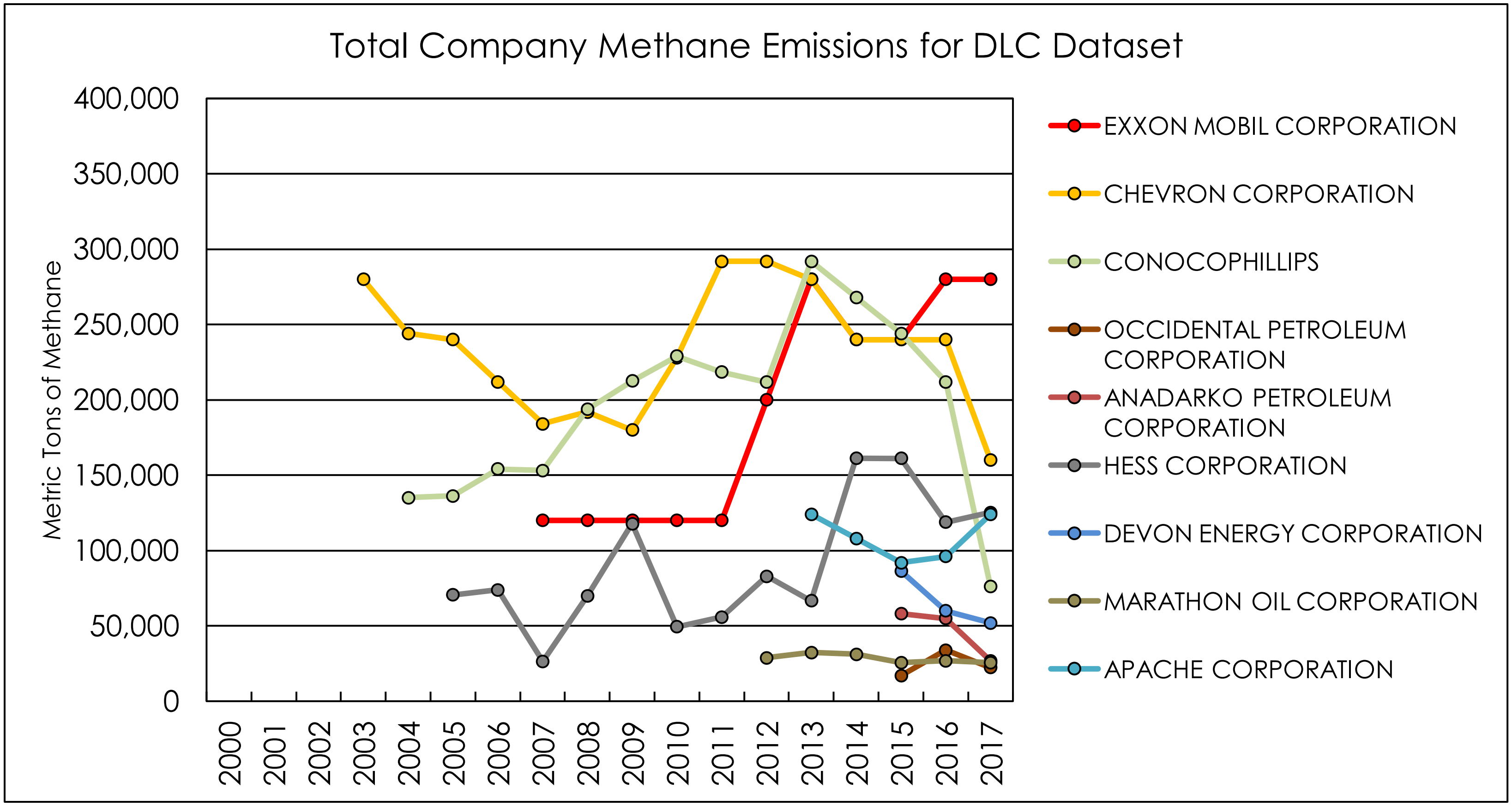

Figure C.6: Total company methane emissions for U.S. CLaSLCs. Plotted from the data available in Appendix A

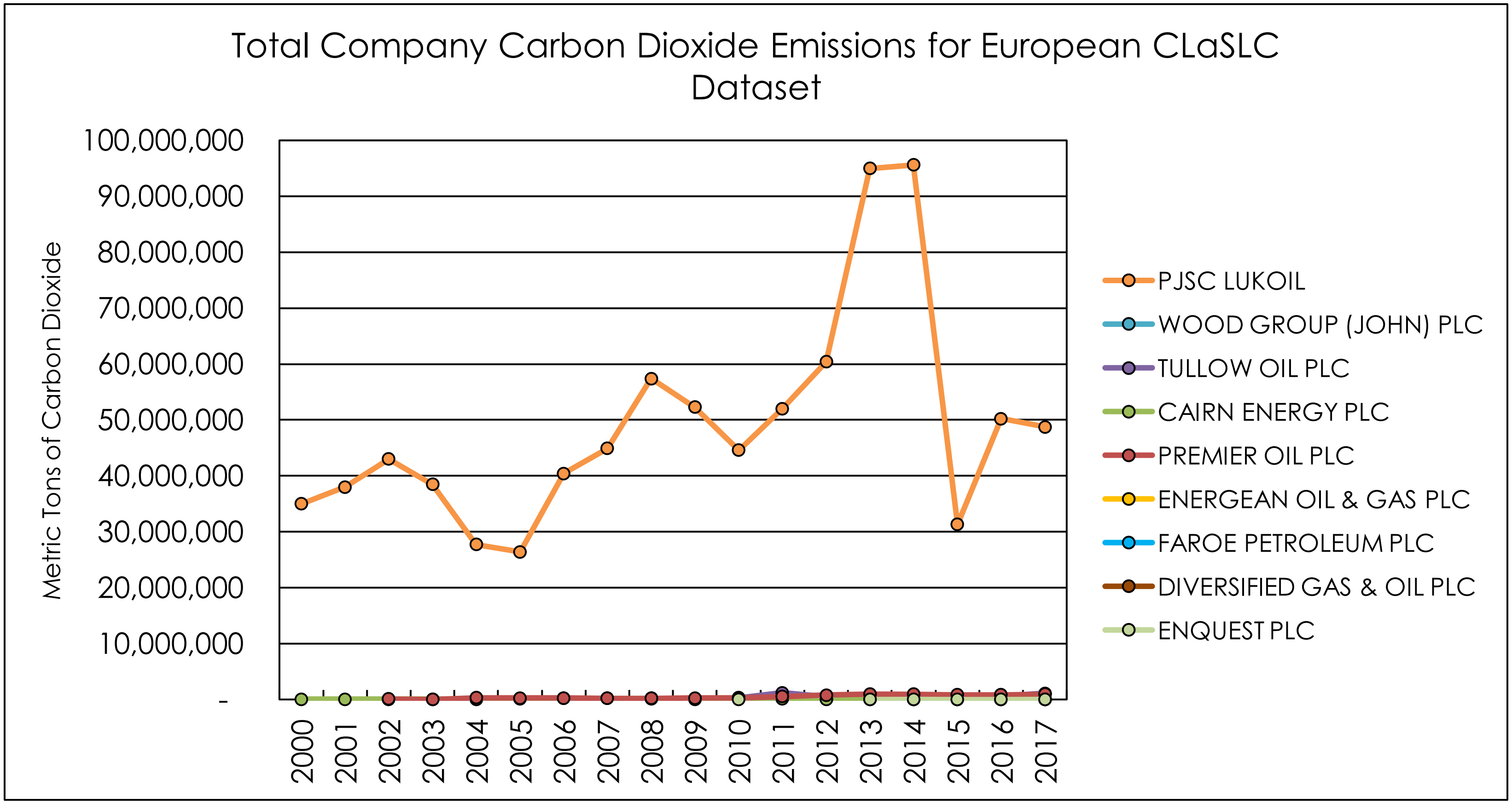

Figure C.7: Total company carbon dioxide emissions for European CLaSLCs. Plotted from the data available in Appendix A

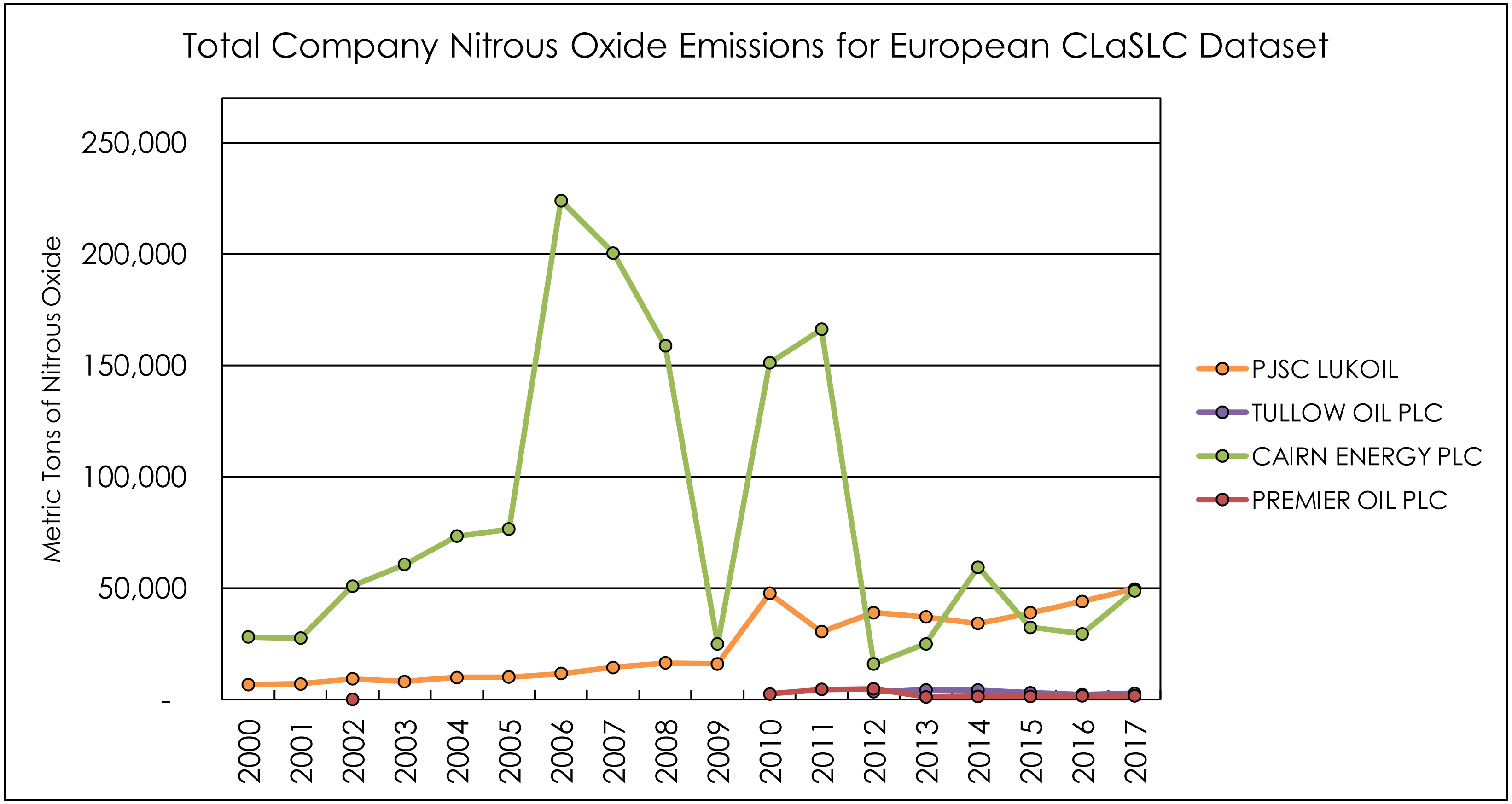

Figure C.8: Total company nitrous oxide emissions for European CLaSLCs. Plotted from the data available in Appendix A. Note that the abnormal readings for Cairn Energy between 2005 and 2012 may be the result of inaccurate reporting.

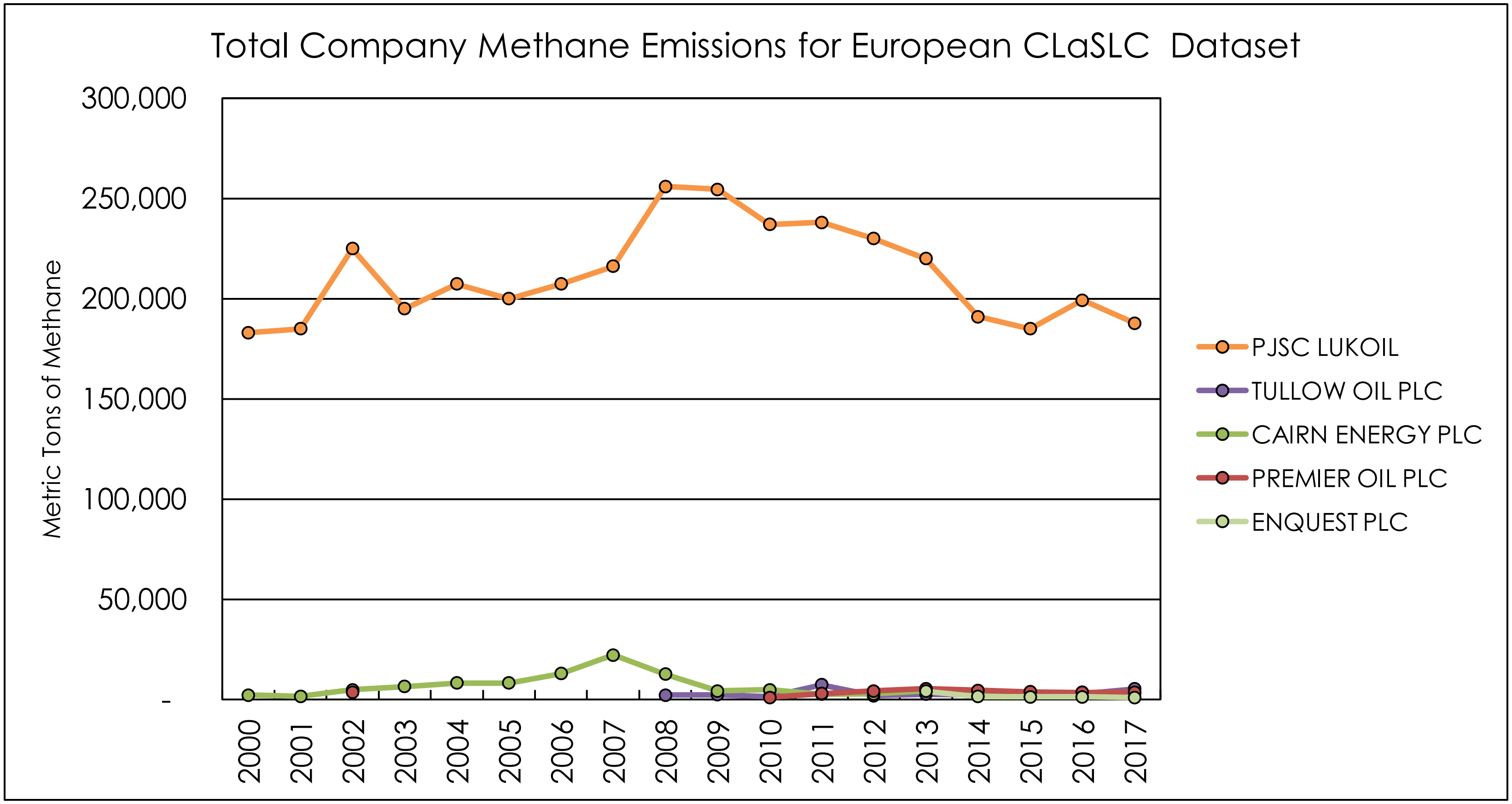

Figure C.9: Total company methane emissions for European CLaSLCs. Plotted from the data available in Appendix A.

Glossary

CER – Certified Emissions Reductions

CLaSLCs – Cross Listed and Single Listing Companies

DLC – Dual Listed Company

EIA – Energy Information Administration

EpMTC – Euros per Metric Ton of Carbon Dioxide

ESG – Environmental, Social, Governance

EU – European Union

EUR/MWh – Euros per megawatt hour

EU ETS – European Union Emissions Trading Scheme

GDP – Gross Domestic Product

LSE – London Stock Exchange

NYSE – New York Stock Exchange

OECD – Organization for Economic Co-operation and Development

ROE – Return on Equity

U.S. – United States

US EPA – United States Environmental Protection Agency

VAT – Value Added Tax

WACC – Weighted Average Cost of Capita

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Vita

Mark graduated from the University of Edinburgh with a BSc (Hons) in Geology prior to attending the University of Texas at Austin in pursuit of a Master of Art in Energy and Earth Resources. Given his concentration in the field of finance he will attend the London School of Economics in pursuit of a Master of Science in Finance and Private Equity during the 2019/20 academic year. Having worked in the energy sector and in financial services it is his intention to pursue a career in the financial sector, focused in investment banking and private equity, following his graduation from the London School of Economics.

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